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# FRANKLIN INSTITUTE,

DEVOTED TO

## SCIENCE AND THE MECHANIC ARTS.

EDITED BY

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FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVI, No. 1. 73D YEAR. JULY, 1898




## Mining and Metallurgical Section.

*Stated Meeting, November 10, 1897.*

## FORESTRY IN RELATION TO PHYSICAL GEOGRAPHY AND ENGINEERING.


BY JOHN GIFFORD,

Member of the Institute.


It is mainly the object of this paper to indicate that, wholly aside from the question of profit in the production of wood crops, the degree of benefit derived from the forest is sufficient to warrant any State in protecting woodland owned by private parties from reckless waste by fire. The State owes to every citizen and his property a reasonable amount of protection against incendiaries and those guilty of criminal carelessness with fire. A country in which the owners of property are at the mercy of greedy and insatiable corporations, malicious incendiaries and wood thieves is still, more or less, in a state of anarchy. The truth is easily

demonstrated that the root of the evil is in civic indifference, a lack of morality and patriotism, and selfish greed which is invariably engendered and actually fostered in forms of government where individual liberty has few limitations, and in many instances in certain localities runs rampant. It is not my intention to dwell upon this hopeless phase of the subject, but to refer briefly to a few of those indirect benefits of the forest, the importance of which cannot be measured in dollars and cents.

The Mangrove on the coast of Florida.

Dr. Karl Eckstein has just written a book on "Forstliche Zoologie," Dr. Frank Schwarz one on "Forstliche Botanik," and no doubt, among the countless German works on forestry, there is one or several on "Forst-Geologie."

The agencies which are active in modifying the structure of the surface of the earth are usually classed as atmospheric, aqueous, igneous and organic. Little is usually said in works on physical geography of vegetal agencies. Geographers generally have neglected to show the action of the

forest in this respect, to note the great changes occasioned in the nature of the earth's surface by forest destruction, and the methods employed in lessening or checking the destructive agencies of nature by means of the forest. It comes within the scope of physical geography to treat of these manifold agencies. Man, a potent agent in changing the nature of the earth's surface, may, by his carelessness let loose the destructive forces of nature by destroying the forest. Fertile regions have been turned into deserts, and floods, avalanches, earthslides, shifting sands, fevers and strong winds have been engendered or accelerated by forest destruction. On the other hand, by the application of forest planting and engineering skill, avalanches, earthslides and floods have been prevented, shifting sands fixed, sterile lands rendered productive, and malarial lowlands healthy. The forest is the instrument by means of which he can harness and control these unruly forces.

Although of great importance in this connection, I shall little more than mention the work of the mangrove tree, the great land-former, which, supplementing the work of the coral-polyp, has added to the warm seashore regions of the globe immense areas of land. These trees grow in salt water several feet in depth; their labyrinth of roots and branches collect and hold sediment and flotage. Thus the shore-line advances. The seeds of the mangrove germinate while still attached to the parent plant. These plantlets fall into the water, float away until their roots touch the bottom, to which they at once fix themselves. Detritus accumulates, birds, wind and water bring seeds and soon the island is richly covered with vegetation and fit for human habitation.

I shall only mention, also, in passing, that vast areas, formerly malarial and swampy, have been rendered healthy by planting the eucalyptus, and that vast fertile regions of the tropical world have been explored and exploited through the aid of quinine, a product of the cinchona tree.

Unlike other crops, the forest constantly improves the soil, provided the litter is not removed or allowed to burn. The roots of trees penetrate to its deeper layers, and absorb

large quantities of mineral matters. A large percentage of this material goes to the leaves, and is deposited on the surface. The surface soil is both enriched by these mineral substances and protected by a mulch of humus in varying stages of decomposition. As the lower layers rot, new layers of leaves and twigs are being constantly deposited, so that the forest soil, in the course of time, fairly reeks with nourishing plant-food, which seeps out more or less to enrich neighboring soils. The German peasants know well the great manurial value of the forest litter. They have, only after years of coaxing and forcing in certain localities, relinquished their rights to litter and pannage in communal forests. These rights, however, under great limitations, are still cherished in various parts of Germany.

Certain vast areas in America consist of many feet of forest detritus. The fertility of alluvial soil is due, at least in part, to fine particles of humus which have washed from forest regions.

The forest not only enriches the soil, but also is a soil-former. Even the most tender rootlet, because of its acidity, is able to dissolve its way through certain kinds of rock. This, together with the acids formed in the decomposition of humus, is a potent and speedy agent in the production of soil. The roots of many species of trees have no difficulty whatever in penetrating limestone and in disintegrating rocks of the granitic series. As the rock crumbles, soluble inorganic materials are released, which enrich neighboring soils, especially those of the valleys in regions where the forest is relegated to the mountain sides and top, as should be the case in all mountainous regions. In view of the destruction occasioned by mankind, it is a consoling fact that nature, although slowly, is gradually improving her waste lands.

If not interrupted, the barest rock and the fallowest field, under conditions which may be called unfavorable, will become, in the course of time, forest-clad and fertile. The most important function of the forest in relation to the soil, however, is in holding it in place and protecting it from the erosive action of wind and rain.

In order to appreciate the beneficial influences of the forest in this respect, we must study the condition of land which has been for a time deforested. We need not visit the washed lands of the South, where large areas have been ruined beyond redemption. It is visible in every field and in every stream. After a rain a potsherd, piece of shell or pebble may be seen resting upon a pyramid of earth, often over an inch in height. Either the earth of the field has been washed away or compacted to that extent by the beating force of the rain.

A part of physical geography, a subject of great interest and a delightful field for investigation, is the study of those forces which have produced the geographical distribution of forests. Why is it that in one part of the Eastern United States there are vast areas of one or two species of forest trees, in others a mixture of many kinds, in others savanna land, in others desert areas, and in others prairies? The winds, the birds, the fires of the aborigines and countless other agencies have all lent a hand in moulding the surface of Eastern America as it appears to-day.

For instance, one tree endures fire better than another, the weakest in that respect in consequence perishes, so that even the species which constitute the forest are, in part at least, due to fires. From the great mixture of trees in swamp lands and in which, owing to dampness, fires have done little damage, we can note all stages to the savanna and prairie lands, which are in part, no doubt, due to fires. It is said that in many parts of the West, when the fires died out with the Indian and the buffalo, forests gradually appeared again. The thousands of square miles of pasturage on the plains and lower hills of Tolima, in South America, were once wooded. Year after year of burning converted this region into pastureland. The trees all perished, with one notable exception—the *Chaparro.* This diminutive tree has been able to survive. It is truly the survival of the fittest. And, so the great conflagrations in the magnificent forests of the Northwest, in our pine forests of the States bordering the Great Lakes, in the forests from Maine to Florida; in fact, everywhere in America where the forests are in combustible

condition, fire is devouring our forestal resources and rapidly changing the nature of the surface of the earth. In regions of dampness the species are manifold, but in dryer portions only the fittest have survived, while in prairie and savanna regions only grasses and sedges are able in the end to endure fire and countless hoofs.

When the forest vanishes there vanish with it conditions of atmosphere and soil which can only be regained by the expenditure of time and energy. Devastation is the matter of a day; reforestation and reclamation mean the expenditure of cash, time and energy.

A forest-road in Baden, Germany.

An important function of the forest is in breaking the force of the wind. On the wind-swept plains of the West even the value of the hedgerow is appreciated. A windbreak of trees is essential to the western farmer. He knows well how the resistless blast robs the land of its moisture, blows down his crops and piles the snow in immense drifts about his buildings. While in Eastern and Western America fires are destroying millions of cords of excellent timber, in the central States they cherish the merest apology of a tree for the protection it affords them, and warm themselves with corn when corn is cheap and coal expensive.

Constructions for the prevention of avalanches in Switzerland.
(Loaned by the Swiss Journal of Forestry)

In southern France belts of trees have been planted along the railroads, because the constant, almost resistless, wind actually impeded the trains.

A forester must thoroughly understand roadmaking in addition to a knowledge of surveying. In many parts of Europe he must understand more of engineering in order to construct the elaborate works for the correction of landslides, avalanches, floods and shifting sands. A forester must be a fairly good botanist, zöologist and geologist, also a surveyor, and, to a certain extent, a civil engineer, besides being thoroughly competent to manage a tract of woodland according to a well-studied plan, and, in addition, have the ability to market the crop in good shape. The significance of the profession is only fully recognized in parts of Europe. Forest exploitation and road construction go hand in hand, so that inaccessible forest regions become profitable solely through the construction of excellent roads. In Germany excellent stone roads penetrate the forest in every direction, many of which are solely for the purpose of transporting forest products.

During the summer of 1896, in company with Dr. Fankhauser, Government Inspector of the forests of Switzerland, I visited the works of correction in the Bernese High Alps, and was both surprised and impressed with the great difficulty and expense of correcting evils which need not have existed had the forest been properly treated.

In many places by persistent work the Swiss engineers and foresters have prevented whole mountain-sides from slipping and huge masses of rock from crushing the villages in the valleys. Their boisterous streams, which are fed by perpetual snow, must be constantly watched, and the young forests on the mountain sides are in danger of ruin by avalanches. By walls of stone, wattle-work and a host of ingenious devices, they chain these forces until the trees they have planted can gain a footing and hold the rocks and soil in place. There will never be need of such work here, except perhaps in Western America, owing to the absence of precipitous mountains, but there is no better place in the world than Switzerland to study the influence of the

forest in lessening in many ways the destructive forces of nature.

The usual means, and the one employed everywhere for the prevention of avalanches if the depth of soil admits, is the plan of establishing bermen. Bermen are narrow ledges or galleries cut in the soil, beset with rows of short piling forming horizontal terraces. Those stakes are driven as deeply as possibly into the ground and firmly wedged with stones. If the soil is not deep enough for stakes, then the so-called snow-bridges are constructed, which consist of logs or beams supported by solid wooden trestles and running horizontally on the declivity, serving to support the stakes, which are driven as far as possible into the soil of the mountain side.

Together with these constructions in the localities where avalanches take their start, reforestation must go hand in hand so that, in view of the extremely slow growth in Alpine regions, the stakes and snow-bridges may not become rotten and wormeaten before the young forest has grown up sufficiently.

Above the timber line the construction of avalanche barriers is mostly a hazardous undertaking. In such regions the use of lumber is precluded because of its limited durability and other reasons. When it is a question of works to be maintained forever, stone alone is fit. Horizontal walls of dry masonry are built, which present a durable and almost immovable obstacle to the destructive snow masses. These horizontal walls are built one above another, according to the inclination of the slope and nature of the surface. For various reasons even within the timber limit the construction of masonry may be indicated.

Let us consider for a moment the great question of floods, which more vitally concerns us than does the prevention of avalanches by afforestation. "It is unpleasant," says the editor of *Garden and Forest*, "to be constantly sounding alarms and predicting calamities. No gift of prophecy is needed to foretell the ruin which will follow if the devastation of the forests of the Appalachian region from Quebec to Alabama goes on for the next twenty-five years, as it has

done. And who can estimate the destruction which will ensue if the floods are let loose from the still loftier ranges which feed the Columbia, the Sacramento or the San Joaquin, or who can imagine the extent of the inland sea that will roll over the Mississippi Valley when the water barriers are removed from the eastern slopes of the great Continental Divide and the sources of that immense water system in the central north? *Common prudence ought to arouse the Legislatures of the various States and of the nation to face this problem now, which is of more vital importance to the life of the republic than any question of tariff or of currency.*"

With a flood plain of 30,000 square miles, and tributaries draining the immense territory east of the Rockies and west of the Alleghanies, the causes and prevention of destructive inundations along the mighty Mississippi are matters of national interest. Millions of dollars have been spent in the construction of levees, which, although necessary, are second in importance to the preservation of the forests and the afforestation of denuded areas at the headwaters of its tributaries. It is said that Eads after completing the jetties remarked that they had been working at the wrong end of the river.

The difficulty is more a matter of mud than of water. The fact that the river empties into a practically tideless gulf causes the formation of a delta instead of an estuary, and the silt deposited by the flow clogs up its mouth and prevents the rapid discharge of flood waters. Another difficulty is the extremely tortuous nature of the river, which causes strain on certain portions of the levees, and slackens the flow, which in turn causes a large deposit of silt in the river-bed, inevitably in the course of time leading to disastrous consequences.

Before attempts at reclamation, in times of floods the river flowed over the natural levees and deposited a rich covering of mud.

Owing to the deposit of mud in the river-bed, it becomes necessary therefore to elevate the levees until the river at last runs in an aqueduct far above the level of the plain, which is deprived of its former share of mud-deposit. Under

such conditions, in spite of vast engineering efforts to solve the problem and save for cultivation the fertile area of the flood plain, the menace of inundation can, perhaps, never be removed. In former times, before the levees were built, the river in times of flood spread over the natural levees into the vast swamp forest along its shores. There was deposited in this forest, owing to the slackening of the flow, a rich covering of mud. Year after year of vegetal and animal deposit produced the fertility for which the region is famous.

Certainly the construction and care of levees will always be a necessity, and a partial amelioration effected by dredging and straightening the channel, or by any means, in fact, which will hasten the flow and discharge of mud into the Gulf; but even this will all be futile unless equal attention is paid to conditions at the water sources. Forests will not only regulate the waters, but will accomplish something which is more important—they will prevent erosion, and thus materially decrease the amount of silt. In the study of every flood, whether a mountain torrent or the Father of Waters, there are three divisions which must be considered and receive attention commensurate with their importance—they are the collecting area, the channel course and the *débris*. In the case of the Mississippi the collecting area has been neglected.

In the case of a torrent the principal mass of water forms in the collecting area. Here, also, erosion begins—imperceptible in the beginning—but soon an immense volume of water descending on all sides into the channel course. At first it is loaded only with silt; soon in the channel course rocks, stones and timber accumulate. This powerful mass, by undermining the banks, receives constant additions until the whole is dumped into the level plain, when the stream emerges with diminished force. It is a combination of thousands of such streams which forms the Mississippi. In conquering a boisterous stream one can make a series of protective works, or by afforestation retard the flow of waters in the collecting area, the source of the evil. In mountain torrents a series of transverse dams are used, behind which

the *débris* is blocked and the stream prevented from digging a deeper bed. Much could be said of these protective works, which have been extensively constructed in France and Switzerland.

The following is quoted from a speech delivered at a meeting of Swiss foresters, by Dr. Fankhauser, who must be ranked among the highest authority on the subject in Europe:

"Many dangerous torrents have been tamed by engineering efforts, to which a large number of places owe the security of life and property against the devastating force of the elements.

"But the conquest of a torrent by means of engineering constructions alone has also its dark side. Where a simultaneous improvement of conditions regulating the water sources is neglected, constructions, in order to withstand for all time the dashing of powerful floods, must not only be built very solidly but must be maintained continuously in their original condition.

"This point assumes great importance even where stone suitable for the work is easily accessible, because it is a question of using a passive and perishable means to oppose living forces, which are inexhaustible and constantly operating.

"On account of the great cost of building and maintaining these works, it is generally necessary to confine them to the channel course, and to stop here the main sources of erosion. But, as we have seen, erosion begins not here but in the uppermost collecting area.

"The gathering of *débris* is not prevented by the construction, only lessened. Every little side rivulet delivers its quota, and in the course of decades all these washings count up to a considerable quantity. As long as the newly built dams are not filled up, sand and stone are held fast behind them, and the results are satisfactory. But when the levelling process is complete, the brook then pours at flood times its material over the dam as easily or more so than before it was built. From the brooks the sediment gets into the rivers, and these again, when they are treated

in like manner, carry it off into the low lands. As sediment cannot be dissolved by water, it remains where the fall is too slight to carry it further, and causes a raising of the river bed.

"It is easy to calculate what imminent danger ensues to neighboring lands from these conditions, in spite of successive costly raising of the barriers.

"But this is not all. As the river rises the level of the underground water also rises until at last the valuable adjacent fields are converted into marsh land, and expensive drainage canals are made necessary. One work leads to another, and yet affords no permanent relief, because instead of holding the *débris* back among the hills, it is only carried further on, and thus at great expense the trouble is shifted from one place to another, not overcome.

"All technical constructions of this sort only aim at providing a barrier. As the French engineer, Surell, in his famous study of torrents has so aptly said, they are measures of defense, but they do not lessen the power of the waters; they only compel them for a moment to keep certain bounds. Entirely different is the effect of the forest. Of course, it is not a question, as many mistakenly suppose, of foresting the overhanging banks and sides of a torrent to prevent undermining and land slides. A wood is as powerless as the soil itself to resist a torrent, and succumbs with the soil to the rush of waters. But in the uppermost collecting area a forest growth holds the accumulations from heavy rain falls and hail storms, and thus prevents the great and sudden swelling of streams.

"Only reflect that the leaves of a medium aged beech forest, if spread out, would cover eight times the area that the growth in question occupies, and it will be quite apparent that even in the hardest downpours almost one-fifth of the water is intercepted by the foliage, and thence flows slowly down the trunks or passes off in vapor."

Then, too, immense quantities of water are transpired by the leaves, often, as with the eucalyptus, several times the amount which falls on the surface it occupies, in the form of rain.

Shifting Dunes near Avalon, N. J.

A forest of *Pinus maratima* on the dunes of Gascony.

A large quantity of water is absorbed by the forest floor, and a large quantity runs to the deeper layers of the soil, through channels caused by the decay of roots. A woods is full of stump holes. A torrent to be conquered must be attacked where its forces are scattered and easily controlled.

Before concluding my remarks on floods, I have yet to mention the willow, that Cinderella of trees, which like the mangrove in the salt waters of the South, is the great land-former along the shores of rivers and other fresh bodies of water in northern latitudes. The willow loves to grow even in abandoned land, utilizing a neglected corner or a poisoned pasture, clothing with abundant green the most hopeless fields, moors and marshes, and although covered at times with water, firmly holds the soils of banks, and constantly catches the sediment, thus increasing the depth and fertility of the soil. At the same time its pliant twigs serve for baskets, fences, racks, wagon-bodies, trunks, boxes, etc. Even here its usefulness does not end, since the horticulturists of our prairie regions have discovered that because of its endurance and rapidity of growth it forms an excellent wind-break.

I have still, in conclusion, a few words to say in reference to the fixation of shifting sands. Although the methods employed in France may not be applicable to America, I can show the beneficial influence of the forest in this respect in no better way than in referring to the results of the work in the Dunes and Landes of Gascony, and in order to be brief shall quote on the subject from my report to the State Geologist of New Jersey.

"In the early part of this century the condition of this territory, which is bounded on one side by the rivers Gironde and Garonne, on another side by the river Adour and on the other by the Bay of Biscay, was in brief as follows: There were miles of marshy, treeless land, covered with a low but dense growth of herbage. It was unhealthy, with but few roads and was very sparsely inhabited. Even to-day, now and then, one of the old time peculiar and picturesque shepherds may be seen watching his flocks, standing on stilts, wrapped in a woolly sheepskin coat, knitting

stockings. It was, in short, a desolate, little known and unproductive country. The ground being perfectly level, sandy and underlain with a peculiar hard pan called *alios*, was poorly drained. There was fever in consequence. *Alios* is a sandstone, the cementing material being organic matter and compounds of iron. Near the shore there were salt ponds, fresh lakes and stagnant marshes. Bordering the sea for miles there were huge masses of moving sand called the Dunes. These dunes arrayed themselves in lines along the shores, moving constantly inland, covering villages, filling rivers and clogging inlets. This aggravated the unwholesome condition of the territory in their lee called the Landes. Early writers state that the sandy Dunes and the marshy Landes were both at one time forested, and that this dangerous condition of affairs was the result of imprudent forest destruction. Imagine the dunes along the Jersey shore clogging up the inlets, the water from the interior flooding the marshes and lowlands. The bays, which are now salt, would then become fresh in consequence, stagnation and sickness would follow, and you would have an exact repetition of what happened in Gascony, all of which is described in detail in the works of Chambrelent, Bremontier and Grandjean. The first and most important step was to stop the shifting sand. This was in part accomplished by covering the surface with brush and then sowing the seeds of the maritime pine (*Pinus maritima*), and finally in full by the construction of an artificial littoral dune. When the tide falls the sand of the beach, ground into powder by the waves, dried by the sun and wind, is blown in the direction of the prevailing winds, which is usually toward the shore. The sand moves like drifting snow until it meets an obstruction, and there a dune is formed equal in height to the height of the obstacle. In order to protect the natural dunes which have been sown in pines, an artificial or littoral dune is constructed. This is accomplished in a very simple but ingenious way. A fence of boards or brush is built in a line along the shore a short distance from high-water mark. This stops the sand which is moving inland, so that a drift forms similar to

snow along a hedgerow. When the sand forms a drift equal in height to the fence, so that the fence is in fact buried, a new fence is constructed on the crest of the dune which has just been formed. So on fences are buried and constructed until the dune reaches the desired height, and if lacking in breadth or too wide, the fence is moved back or forward a little to suit the desires of the forester or engineer in charge. By the use of palisades or brush an artificial dune can be easily and cheaply constructed. The dune should have a gentle slope toward the ocean. When the dune has reached the proper size and shape it is necessary to plant its windward slope in *gourbet* in order to hold the sand in place. The *gourbet* or sand sedge has rhizomes many feet in length, by means of which it fixes the sand. This huge bank of sand is constantly watched and kept in shape.

"In traveling along the beach from the mouth of the Garonne to the mouth of the Adour, one sees squads of men and women working on this immense ridge of sand, planting *gourbet* here and there or digging it up in places in order to keep the dune in perfect shape. The vast plantations of pine and the villages in the neighborhood of the dunes owe much to the humble but persistent gourbet. Where were once nothing but huge, barren, shifting dunes are now beautiful pine forests close to the shore of the ocean—the location of several delightful resorts, with the pleasures of the sea and forest combined. Back of the dunes in the Landes, canals and drain-ditches were dug through the impermeable *alios.* Pine seeds were sown, and, through the efforts of engineers and foresters, the region changed to such an extent that a new province was really added to France. The Hugue method of turpentine-orcharding was adopted, the main principle of which is to prevent excessive bleeding.

"With the advent of railroads, forest fires increased, requiring the construction of fire-lanes and the employment of watchful wardens. The soil and people improved, and, thanks to de Villers, Bremontier, Chambrelent and others, the Landes is one of the most interesting and prosperous regions of France.

"Along the coast of America there are shifting dunes. At Avalon, New Jersey, a huge bank of sand is slowly but surely destroying a beautiful forest. It could be stopped at slight expense. These dunes are moving inland over the marshes, leaving their natural beds so that the marsh mud is exposed on the ocean side, and the beach becomes unfit for bathing purposes."

Destroy completely the forest which covers the coastal plain of Eastern America, and it will become a bed of shifting sand, unproductive, unsightly, and unfit for habitation, although capable of producing an abundance of valuable timber.

I have merely mentioned subjects, every one of which would be sufficient for a lecture. It has been my endeavor to show, however, that there is more to the subject of forestry than the mere production of a wood-crop, although, no doubt, out of the American lumbering methods of to-day an American system of forest management will be in time evolved.

*Stated Meeting, May 11, 1898.*

## GOLD MINING IN GEORGIA.

BY WM. TATHAM,
Member of the Institute.

I propose in this paper to give some account of the gold mines and mining in Middle Georgia. Middle Georgia is a sharply rolling country, with few high hills or mountains. In Wilkes County is Graves Mountain, which consists of three elevations rising some 1,000 feet above the surrounding country, celebrated throughout the world for the beautiful crystals of rutile found there, and which are so much admired in almost every mineral collection. Further towards the north, in DeKalb County, about 20 miles from Atlanta, is Stone Mountain, a mass of intrusive granite, which supplies stone for paving blocks and building purposes throughout the South. The climate is temperate. In the summer

the temperature rises to an average of 80°, and in winter it rarely falls much below 32°. In some instances the mercury has been known to drop to zero, but such cases are rare.

The mines I purpose to describe are in that gold belt, sometimes known as the Carolina belt, which extends in a general northeasterly direction through Wilkes, McDuffie, Columbia and Lincoln counties in Georgia, and Abbeville and Edgefield counties in South Carolina. It is on the southern edge of the great belt of Virginia, the Carolinas and Georgia, which was the source of the gold produced in the United States prior to the discovery of gold in California.

The history of gold mining in Middle Georgia dates back to the early part of this century. The Columbia mine in McDuffie County was discovered about the year 1812, and later on, among others, the Parks, the Walker and the Seay mines in the same county, and the Magruder in Wilkes. It is worth noting that, while in North Georgia the first mining was entirely in placers, in Middle Georgia the gold came entirely from vein mining. I know of but two instances in that section where any amount of gold has been taken from surface washings, the Sales mine in Wilkes County, and what is known as the Camp Ground, in McDuffie County. This does not apply, however, to the northeastern part of the belt in South Carolina, where surface washing has been carried on from time immemorial, and, indeed, is to this day a source of income to the residents of the small valleys in the northern part of that State.

The gold occurs in quartz veins, associated with galena, pyrite, chalcopyrite and zinc blende. In some instances these veins are well-defined fissures, but in many cases they are segregations, sometimes very large and persistent, and again an aggregation of small stringers in which the gold is by no means confined to the quartz, but is disseminated in the adjoining rock. Sometimes these deposits are very rich. In the Dorn mine in South Carolina some $300,000 was taken from one rich pocket, and ore which did not yield over $100 per ton was considered poor. It is related of the owner of this property that, seated on his verandah, he would exclaim every time a blast was shot, "There comes

another nigger." A good "nigger" in those days was worth $1,000 to $1,500, which is rather good as the result of a single blast.

The Magruder property, in Wilkes County, is another example. Here there were fissures carrying gold, silver, lead and copper, not apparently varying as depth was attained, and also large segregations carrying on the surface gold only, but which in depth (about 250 feet) carried a mixture of galena and zinc blende, which did not contain sufficient valuable mineral to make their development profitable.

I have smelted quite a large amount of galena from this mine, which ran on an average 40 per cent. lead, 40 ounces silver to the ton and $15 in gold, and some copper not determined. There was a good vein of this ore, but the owner abandoned it to sink, on a segregation, after gold. In general, these segregations consist of a sugary quartz showing gold in the pan and shading off into the country rock. They are sometimes as large as 30 feet wide, and may be traced for long distances; but in the greater number of cases, where they have been followed much below water-level, the ore has turned out refractory and of but little value. There has not been, however, sufficient work done on this class of veins to settle definitely their general character.

The fissures, on the contrary, seem to hold their value in depth. Of course there is less free gold than in the upper portions where the sulphides have been oxidized, but the assay furnace will show about the same amount in gold throughout. I do not mean to say that there is no free gold below water; in veins which I have worked in McDuffie County I have found free gold well below the limit of oxidation—notably in one or two veins where the gold occurred in coarse grains embedded in a mixture of galena and pyrite.

I should mention one peculiarity of the quartz veins in McDuffie County, where I worked. In that locality water-level is found about 40 feet below the surface. At water-level the veins are generally more or less shattered, and contain but little gold, but on sinking a short distance below water they "make again," as the miners say, and attain

their original size and richness. It is an almost invariable rule that a good outcrop followed to water and found almost worthless at that point will repay further expenditure in sinking to a greater depth. There are exceptions both ways —sometimes the vein holds good all the time, and sometimes you do not find the vein again, but the rule holds good.

In my section in McDuffie County the veins almost always show pyrite and galena in the pan whether free gold be present or not.

Before the war, when slavery prevailed, the planters used their hands in mining gold in the intervals between the harvesting of the crops. Some of them kept a trusty negro prospecting for rich outcrops. One old negro whom I knew, spent all his time in this pursuit. If he found a valuable outcrop, he had the promise of a good drink of whiskey, while, on the other hand, if nothing resulted after a reasonable time, he had the certainty of a good whipping. Stimulated thus by hope and fear, the strongest incentives to human endeavor, he made remarkable discoveries, and his owner made, for that country, a great deal of money.

The outcrops thus found were followed to water and then abandoned for new discoveries. While this method of mining was profitable for the planters, it was disadvantageous to their successors. The cream had been taken from all the known ore bodies and nothing was left to guide the newcomers but the remains of abandoned surface workings.

Owing, however, to the rule quoted above, parties with sufficient capital could sink on the old workings with reasonable assurance that the result would repay their outlay, and this is the method of prospecting in that part of Georgia to-day. Of course, the early workers did not discover all of the paying outcrops. There are some still left to make the finders happy, but in my section they are like angels' visits, few and far between.

In the early days of mining in Georgia the mills were of a very primitive description. The stamps were squared pieces of timber armed at the bottom with an iron shoe.

The cam shaft was generally made of wood with projecting pieces which lifted the stamps by striking pegs fitted therein. The motive power was generally water. The mortars were sometimes of iron, but a very convenient substitute was a wooden box filled with pieces of quartz stamped dry, which, when properly worked, formed an excellent bed upon which the ore could be crushed. Instead of screens a plain board was put in front of the mortar over which the water splashed and carried off the finely-ground rock held in suspension. The pulp was run over blankets and the gold thus collected.

In the Columbia mine recourse was had to a number of patented gold-savers, and the fact that the mine was nevertheless successful is sufficient testimony to the value of the property. I had occasion to sample several thousand tons of tailings from stamps at this mine, and although the ore was undoubtedly very rich, I was not able to find more than a very slight value in the tailings, a fact which speaks volumes as to the good practice at that time. In explaining the good work at that mill, the old superintendent said to me: "You know, Mr. Tatham, there was a leather strap hanging up in the mill all the time, and if any of the boys failed to do his work properly he got a good taste of it."

In later days came the iron stamp mill, with plates inside the battery and silver-plated copper aprons, but I question very much if better results are obtained with the new machinery, so far as free gold is concerned, than was had in the old days with the wooden stamp and the leather strap. Of course, much more rock is put through in a given time, but the percentage of yield will be about the same. In those parts of the gold belt, in which placer ground could be worked to advantage, the old-fashioned rocker and long-tom are still in vogue. I have seen them in active operation. The advantages of modern machinery in the South are: (1) an increased production with a given power and number of hands, thus cheapening the cost of milling; and (2) in the improved method of concentration.

The old miners, almost without exception, worked for the free gold in the ore. I say *almost*, because there were some,

a very few, who recognized the value of the sulphides; it was a favorite plan with these people, far in advance of their age, to mix the iron sulphides with wood ashes. The mixture of ashes and sulphides, moistened with water, was allowed to weather for some time and was then put into the mill with the ore. The results are said to have been very satisfactory. Probably soluble sulphates of potash and soda were found together with iron oxide and free gold.

But these pioneers in the chemical treatment of gold ore formed a very small minority. The greater number of gold seekers were content to take the free gold in the ore, leaving the rest to take care of itself; consequently, as soon as the ore presented any difficulty in the way of extraction by simple amalgation, the vein was abandoned for some other surface workings. We have here the explanation of the innumerable surface workings alluded to, and the reason why the work was seldom pushed below water. When the gold remained free, as in some parts of the Columbia mining property, they sank far below water-level.

Twenty years ago gold mining in Georgia was restricted to the remains of the old surface workings and to new finds, but, since it has been discovered that complex gold ores may be cheaply treated, a new era has opened for the southern gold fields.

There is no question as to the amount of gold in the South. We have here a vast territory comparatively unexplored, except that it has been established that there are innumerable veins, carrying free gold to water, and, as a general rule, below water, where the gold is mostly associated with mineral, which makes it impossible to extract the precious metal by the simple process of amalgamation.

In by far the greater number of cases there is enough free gold in the ore to pay for mining and milling, and the value in the concentrates is pure profit. When we have a pure pyrite concentrate we may chlorinate, as is done so successfully at the Haile mine in North Carolina to-day. If we have a mixture of pyrite and galena, we have the choice of the cyanide process, or we may ship our product to smelters, when it can be worked in the lead blast furnaces.

In any event, the gold may be extracted at a moderate cost and with a small percentage of loss.

It is the belief of many well-informed persons that in the near future the gold production of the Southern States will show an increase over that of the past. It would seem as if all the essentials to successful mining were present. Cheap and good labor, a kindly climate and nearness to bases of supply afford conditions which are almost ideal.

There has been no deep mining in Georgia, and it is impossible to say what results may be obtained. So far, however, as our limited observation goes, the facts would seem to justify the expectation that the fissure veins will continue to carry gold in depth, although it may be associated with mineral which will require metallurgical treatment of the concentrated ore, which, however, is no longer the bugbear it was in times past.

Further, in many parts of Middle Georgia the metals lead and copper, associated with the gold, give promise of affording valuable by-products, which will, in many cases, more than pay the cost of freight and treatment at the smelting works.

The concentrates run high in gold. I have had assays of \$500 to \$600 per ton, and the average of concentrates from several thousand tons of ore taken from the property in which I am interested will be from \$100 to \$150 per ton; the silver content varies with the percentage of lead in the concentrates. Nearly pure galena has shown 60 ounces per ton.

The ore is not difficult of concentration. The gangue is mostly quartz, and all the mineral in it is worth separating, so that that problem is easy of solution. The Frue vanner, the Embry or the Golden Gate will do the work effectually. For crushing the ore I prefer the stamp mill with amalgamation in the battery, with a sparing use of sodium amalgam. By this method, the free gold saved by first operation will generally be found more than sufficient to pay the cost of mining and milling.

The gold fields of Middle Georgia afford a first-rate oppor-

tunity to persons with the necessary capital and experience. Land and mining rights can be acquired at very moderate prices. Wood for fuel and mining timbers is cheap, and the price of labor, when compared with the western mining wages, is very low.

There have been many failures in this section, but they have been generally caused by a total lack of knowledge of proper methods of mining and milling, or by insufficient capital, or both. But, so far as that is concerned, the whole mining region of the United States is strewn with wreck due to the same causes.

The residents are ready and anxious to welcome parties seeking to develop the resources of the country, and any one who goes down there to do *bona fide* work is sure to be treated with consideration, courtesy and old-fashioned Southern hopitality.

*Stated Meeting, April 13, 1898.*

# MINERAL RESOURCES OF CUBA.

By Raimundo Cabrera.

Translated from the Spanish by Louis Edward Levy, Member of the Institute.

The receipt of the invitation extended to me by the honorable President of the Franklin Institute of Pennsylvania to present before that widely-famed scientific association an amplification of "Some Notes on the Mineral Resources of Cuba," previously published by me in the *Engineering Magazine*, affected me with two opposing impulses; on the one hand, the consciousness of my inability to do the subject its full measure of justice, and, on the other, my desire to prove my high appreciation of the honor accorded me.

The latter impulse prevailed, strengthened as it was by my natural desire, as a Cuban, to bring to publicity in the industrial centers of this great Republic the incalculable riches which lie in the open lap of my teeming but unfor-

tunate land, ungarnered and almost unexplored, after more than 400 years of European colonization. Thus suggested, my consideration of the subject will avoid a treatment of its technical, purely geologic or strictly scientific aspects, and will be confined to a brief review of data collected from official statistics and from various other competent and authoritative sources, sufficient to indicate the still incipient status of the mining industries of Cuba.

From the time when Cuba first attained any considerable degree of commercial importance it has appeared to the world as a country devoted almost exclusively to agriculture, and even in that branch as limited practically to the cultivation of sugar cane and of tobacco, and to the industrial manipulation of these products. As a source of supply for these two staples, in regard to both quantity and quality, Cuba has commanded universal recognition. But the mineral resources of Cuba, like many other of its rich natural endowments, have been almost entirely neglected, notwithstanding that from the early stages of the settlement of the country, the location and extent of these mineral deposits have been definitely known. Scientific explorations by competent investigators as well as by various in dustrial undertakings, most of the latter, indeed, tentative and ineffectual, have indicated the existence of these deposits at various points of the island. Quarries of white and veined marble, of granite and quartzites, have, in fact, been developed and worked to advantage, mainly, however, for merely local requirements. But besides these, there are to be found in various parts of Cuba, and only waiting to be developed, many of the most valuable of the metals and minerals of modern commerce. Placer deposits of gold and quartz lodes of silver have been worked in a more or less primitive fashion from time to time, since the days of Columbus. Of other metals and minerals which occur in workable quantity in numerous localities, the following may be mentioned: Copper, hematite, magnetite, manganese, asbestos, sulphur, talc, quicksilver, coal, antimony. feldspar, onyx, serpentine, gypsum, baryta, asphalt and petroleum. Specimens of all these, as well as of a variety of vegetable

resins, were exhibited at the Amsterdam Exposition of 1883, and at the Columbian Exposition in 1893.

The causes which have resulted in the neglect of the mineral industries of Cuba are well and widely known and are of such a nature as to be in detail beyond the purview of the present paper; but it may be stated in general that directly or indirectly the condition is due to the administration of the fiscal system of the country, which, with oppressive tax levies on all industries, on all articles of use and consumption and especially on the importation of machinery and the exportation of products, has barred the influx of extraneous capital and labor while repressing the development of the same at home.

In spite of all this, however, the fifteen years preceding the outbreak of the present civil war saw much material progress in the mining industry of Cuba. This was due to a partial relaxation by the home government, under the pressure of the liberal classes in Cuba, of the restrictions imposed on this industry. The introduction of important, though by no means adequate reforms in the system of taxation which had militated so positively against its development, opened the way in this direction and revealed a wide horizon of possibilities for the employment of capital and labor. Such, for instance, was the law of April 17, 1883, exempting the properties of iron mines from the land tax during twenty years, freeing the ores of iron from export duties and relieving from import duties anthracite coal landed at the mining ports, and destined for use in the mining and metallurgical industries. There still remained, however, the heavy import duties on the machinery and appliances required in the work, as well as the port charges of 50 cents per ton on the ships engaged in the traffic, and these imports prevented that extension of the iron industry which the removals of the other restrictions had seemed to promise.

Four years later (June 30, 1887) the above-mentioned concessions were extended to include the ores of maganese, zinc and lead, but were limited to the workings already registered, all new undertakings being required to pay the land tax.

Later again, by royal decree of July 7, 1892, the Spanish administration retraced its steps and reimposed a tax of 2 per cent. on the gross product of all mineral workings, eliciting the protests of the mine owners that the sanction of the franchises previously accorded had led them to large expenditures on their plants, and that the new impost would compromise them in their foreign contracts. These protests, however, were unavailing; the old tax system was gradually reimposed. The result was that for each hectare (2·47 acres) of area, the mining properties had to pay a tax of $5 per annum, to which was added a surcharge of 50 per cent., making $7.50. In addition to this there was the tax of 2 per cent. of the gross product, amounting to 1 per cent. per ton of iron ore, and 2 cents per ton of maganese, and this, apart from the local municipal tax levies. Thus were thwarted the efforts which were being put forth in Cuba in this important branch of human industry.

THE MINERALS which had been more or less constantly mined in Cuba, up to the outbreak of the present revolution in February, 1895, were the following:

(1) Asphaltum and mineral oils.
(2) Copper.
(3) Iron.
(4) Manganese.
(5) Gold.

The deposits of hydrocarbons, asphalt and mineral oils are extremely abundant and of excellent quality, both for fuel and lighting purposes. They are present in various conditions solid, plastic and liquid, and several experts have affirmed "the existence at a great depth of very light oils, petroleum or naptha." Of these, however, no definite investigations have been made, nor scarcely any examinations beyond such as are incidental to a very primitive stage of industry. On the Motembo estate, Province of Santa Clara, at a location named San Juan, borings were made in 1881, which resulted in discovering, at a depth of 95 metres, a deposit of naptha of extraordinary purity, colorless, transparent as water, inflammable, leaving no residue after combustion, and of a density of 0·754, which congealed at a temperature of 85°

C., dissolved asphaltum and the resins, and which was so volatile that its vapor at ordinary temperature could be utilized as illuminating gas. Nevertheless, this well was abandoned after the workings had reached a depth of 290 meters, although the supply continued at that depth.

A well similar to that at Motembo was discovered at Lagunillas, Province of Matanzas, from which, out of a source at a depth of 25 meters (82 feet) there overflowed a supply of 70 liters (18½ gallons) per day. This also has never been further explored or worked.

In the same Province, at scarcely a kilometer from the northern coast, there exists a deposit of bituminous shale impregnated with asphaltum of a high degree of purity and in great abundance, whose workings, though favored by facilities of transportation, have also been abandoned. But even at the Bay of Cardenas, in the Province of Havana itself, there has been found a similar deposit; this latter appears, from contemporary mollusks and corals embedded in it, to be of comparatively recent geologic age.

In the rocks underlying a large extent of the bottom of this bay are great masses of asphaltum in a liquid state, having in places a thickness of 70 feet, and quantities of this have been carried to market in New York, where it was highly appreciated for its purity, and was sold at prices varying from $80 to $120 per ton. The exploitation of these deposits in the layers at shallow depths was begun with considerable success, but the enterprise languished for want of facilities, and eventually failed entirely through the fatal legislative interference inevitable in that unfortunate country, and the concurrent obstacles which develop in multiplicity under the vicious influence of misgovernment.

Asphaltum is to be found extensively in the Provinces of Havana and Pinar del Rio. In the former, there are being worked the mines of Potosi and Santa Rosa, distant half a league by rail from the harbor of Havana. The deposits exploited are embedded in the cretaceous marls and the serpentines which are met with in the northern districts, the strata running generally N. W. and S. E., in veins of about 6 meters. The material is earthy and impure,

but is advantageously utilized as fuel in grates and ordinary stoves. The mineral is worked in a very crude manner, in the open air, and small quantities of the product have been exported annually. In Pinar del Rio are the Canas and Tomasitas mines, close to the beautiful bay of Mariel. These mines are notable for their size, the veins being 35 feet wide, and from 45 to 90 feet deep. They produce over 1,300 tons annually, destined for the use of nearby plantations, whose owners combine in working the deposits, the operations all being carried on in the open air. Asphaltum, or "*chapapote*," as it is called in the country, is very abundant in the Vuelta Abajo, where it commonly occurs spread on the ground as it has been disengaged from the rocks. There are many smaller workings, among them, that of Santa Helena, at Bahia Honda, which district contains unworked deposits of an asphaltum of great brilliancy and purity, which would doubtless be greatly appreciated in the market.

COPPER has been mined on a larger scale than any other of the mineral resources of Cuba, particularly in the Province of Santiago de Cuba, where it was extracted in large quantities until the disturbances of the revolution of 1868 put an end to the industry.

The town of Cobre takes its name from the adjacent mines, which attained celebrity for their great richness and which were worked by a corporation known as the "Consolidada," with a capital stock of £40 sterling per share. These mines were discovered about the middle of the sixteenth century, but their working was reserved for itself by the Spanish Government, with the result simply of their being given over to various contractors, who, without capital or security, sought to profit by them without accomplishing more than keeping more competent agencies from attempting the work. Subsequent to 1833, and after much tribulation and expense, the Consolidado Company discovered some large and profitable lodes, and this not only gave that enterprise a great impetus, but also stimulated the inception of competing enterprises, one of which undertook the development of a number of mines, under the owner-

ship of an English syndicate, with a capital of $300,000, and named the Santiago Company.

The mines of Cobre, of which the machinery and outfittings were destroyed by the insurgents during the so-called Ten Years' War, and the workings wholly abandoned, were subsequently acquired, during the succeeding interregnum of peace, by the Cobre Railroad Company, which energetically undertook the re-establishment of the plant. The company constructed five iron bridges, equipped the workings with tramways, rolling stock and locomotives, importing the material requisite for the purpose, but the efforts thus put forth remained unproductive, and the enterprise was practically abandoned, not by reason of any deficiency in the mines themselves, whose great productiveness is widely known, but solely because of the obstacles created by the administration and by the difficulties with which every enterprise in Cuba is overwhelmed in a struggle for existence against the insatiable hydra called "The Revenue." The exploitation of the mines has dwindled to a reworking of the tailings of the early rich outputs in the mounds of *débris* which cover the ruins.

Other veins are being worked in a more or less primitive way, utilizing the waters which filter from the cavities of former workings, precipitating the copper by means of iron and thus obtaining the copper in a refined state. Of this product 700 quintals were exported in 1885.

The cupriferous zone of Santiago de Cuba embraces three divisions: the district of Cóney that of the Cauto and the district of Cobre. The two former remained unworked; the owners of the mining rights appear to be content to preserve their franchises awaiting better times, having assured themselves of the existence in their concessions of rich veins of native copper, and of its sulphides, oxides and other forms.

According to the able report of Señor Salterain, "quite superficial diggings have disclosed a ferrugineous ridge of 8 meters width, traversed by veins of copper sulphide, copper oxide, carbonate of copper, copper pyrites and native copper, all the veins rich in mineral contents, and which at bottom are probably joined in a single lode of copper sul-

phide, as suggested by a study of the mines of La Caridad, opened in 1882, of those of Portes and others, and of the associated minerals."

In the province of Santa Clara mining concessions have also been allotted, notably at Malejas and at Nicaragua, which have been superficially worked, and which both Spanish and foreign investigators have pronounced as of great importance and promise. Finally, in the provinces of Mantanzas and of Pinar del Rio, considerable copper deposits have been found, the mining of which, occasionally attempted by some crude worker, was always very soon abandoned.

To sum up, I may say, with regard to this subject, that while the discovery of veins of copper has proceeded with great activity in Cuba, as is evidenced by the large number of mining concessions which the Government has granted to individual proprietors (of whom in the district of Cobre alone there are more than fifty), this activity has been due primarily to the facility with which the deposits have been found. Furthermore, however, the general inactivity in exploiting the concessions has been caused directly by the public administration, in a country overburdened with onerous imposts on even the most minute details of industry. The land itself is a veritable mine of wealth, whose productivity is exhausted by the implacable voracity of the tax gatherer. No further comment is needed than the fact that in 1881 the export of copper amounted to only 35 tons.

IRON: Nature appears to have endowed the Province of Santiago de Cuba with its greatest gifts of mineral wealth, and as in the case of copper so likewise in that of iron, the most extensive deposits are found in that province. Large masses of hematite and of magnetite are there to be found, of which a number of deposits extend eastwardly at distances of from 12 to 50 kilometers from the city of Santiago, and about 6½ kilometers from the coast. Numerous mining concessions have been granted in this vicinity, divided into some sixteen groups, named respectively from the towns around which they centre; but, of all these concessions only three are being actually worked, and these by an American

corporation, the Juragua Iron Company. This concern has undertaken operations of genuine importance in the mines named Juragua, not only as regards the mining itself, but also in the transportation of the mineral to the coast and the shipment of the ore at the wharves. For this purpose a railroad, several bridges and extensive wharves have been constructed at a point called Cruz, on Santiago Bay, where the ore is loaded into vessels carrying about 2,500 tons.

The success attained by this Company, whose output has grown from 21,798 tons, in 1884, to nearly 350,000 tons in 1893, stimulated the inception of other similar enterprises in the district of Santiago de Cuba, but though on every hand the bowels of the earth were fraught with a rich store of mineral wealth, and its surface teeming with fertility, the proprietors of the many concessions which were sought and obtained, following the examples of the owners of the copper mines, have been content to guard their rights and to retain their holdings in the hope of a better governmental system, under which capital and labor would be attracted to the task of wresting its stores of wealth from the lap of this prolific yet unhappy land.

A number of other corporations like that of Juragua have been organized by foreign capital, notably the Spanish American Iron Company, which has undertaken the building of a railroad of 6 kilometers length to the mouth of the Diaquiri, and the establishment by dredging and other works, of an artificial port at that place, and the Sigua Iron Company which has begun the working of several mines in the group of Arroyo de la Plata. The total exportation of iron ore from Santiago, since the mines were opened in 1884, has been upwards of 3,000,000 tons.*

* Through the kindness of Mr. John Birkinbine, the President of the Franklin Institute, I am enabled to add the following detailed data regarding shipments of Cuban iron ores.

The Juragua Iron Company, limited, was the initial producer of iron ore in the Santiago District, its first cargo being sent forward August 7, 1884. The Sigua Iron Company did not ship any ore until October, 1892, and the Spanish American Iron Company made its first shipment, May 27, 1895.

The production of each of these companies has been as follows:

MANGANESE also is extremely abundant in Santiago de Cuba; numerous claims for the mining of this mineral have there been located, and a few of them recently put into operation. At Alto Songo veins of manganese dioxide (pyrolusite) are developed to a considerable extent in red jasper and metamorphic formations.

The mineral sites of Santa Margarita, Isabelita, Bostoyo and other localities, have revealed important deposits, though but slight effort has been given to develop them. The most notable workings at the present time are those of Cristo and of Ponipo.

In general the manganese deposits are worked by the people, who take them under lease from the proprietors, paying a royalty of so much per ton. Thus the mining of this mineral, so esteemed as to have been awarded a gold medal for its quality at the London Colonial Exhibition, proceeds on but a trifling scale, being furthermore restricted by the difficulties of transportation, which is mostly by means of wretched ox-carts over miserable roads. Everything is incipient, everything primitive. Many important mines have had to be abandoned simply because of the cost

| Years. | Juragua. Tons. | Sigua. | Spanish American. | Total. Tons. |
|---|---|---|---|---|
| 1884 | 21,798 | — | — | 21,798 |
| 1885 | 81,106 | — | — | 81,106 |
| 1886 | 111,710 | — | — | 111,710 |
| 1887 | 97,711 | — | — | 97,711 |
| 1888 | 198,040 | — | — | 198,040 |
| 1889 | 256,278 | — | — | 256,278 |
| 1890 | 362,068 | — | — | 362,068 |
| 1891 | 266,377 | — | — | 266,377 |
| 1892 | 322,527 | 7,830 | — | 330,357 |
| 1893 | 348,663 | 14,022 | — | 362,685 |
| 1894 | 150,440 | — | — | 150,440 |
| 1895 | 311,053 | — | 74,991 | 386,044 |
| 1896 | 298,299 | — | 114,101 | 412,400 |
| 1897 | 244,817 | — | 206,812 | 451,629 |
| Total . . | 3,070,887 | 21,852 | 395,904 | 3,488,643 |

In addition to the amounts given above for the Juragua Iron Company, limited, which represent the imports, four cargoes of 10,131 tons were lost at sea.

of transportation to the place of shipment, though over but a short distance, made the product unavailable.

The manganese exported up to 1891 amounted to 34,308 tons, which obtained in the United States a price ranging from $10 to $14.35 per ton, according to its composition.

GOLD which abounds in the provinces of Santa Clara and Santiago de Cuba has not, up to the present time, afforded any contribution to the public wealth or general industry of Cuba. All the various scientific explorations and individual prospectings which have demonstrated the existence of important veins of this metal have resulted in nothing, for lack of capital and means of operation, which are ever shy of undertakings in a country where the political unrest which has produced throughout the century such numerous catastrophes, has made all enterprise insecure.

In the district of Placetas, near Guaracabuya, there are a number of mineral sites of importance. Senor Fernandez de Castro, Civil Engineer, in a notable paper published in 1865, states as follows:

" In the mine of Guaracabuya the serpentine, which constitutes the subsoil, appears mottled with irregular veins, some of them quite marked, in which at a glance may be seen the particles of gold, disseminated on the surface in minute scales or nodules more or less connected." In 1865 explorations were renewed to determine the extent and depth of the gold lodes in Guaracabuya, and according to the report made by Senor Saltarain, mining engineer, these investigations indicated the existence of three distinct lodes. But the workings begun were soon abandoned, not only for lack of adequate means and appliances, but furthermore by reason of the revolutionary convulsions that began in 1868 and continued throughout the ten succeeding years.

A similar fate befell the mines of Las Meloneras and of El Descanso, in the same province, and those of Holguin, in the province of Santiago de Cuba. At the latter place, according to the reports of Señor Fernandez de Castro, of Leon Owen, an English mining engineer, and of other experts, there exist a number of gold deposits, among them that of Monte Verde, in the Guayavales section, where there

are three veins that have been worked in former generations. These reports indicate that this region contains a number of separate auriferous lodes, which appear to afford assurance of continuance to a considerable extent and depth.

The value of the gold deposits in the island of Cuba has long been recognized. Several remains of ancient workings have indicated that these deposits mere mined by the aborigines; historians of the discovery of the island have noted the gold ornaments which the natives presented to the Spaniards, whom the quest for gold attracted with greater avidity to the neighboring continent, in Mexico and Peru, where they found it, mined and worked in more dazzling quantities, in the hands of the subjects of Montezuma and the Incas; but certain it is that while unfortunate Cuba retains rich veins of gold in its unexplored soil, its people have not yet seen a single coin of the precious metal obtained from that store.

Perhaps the future reserves for them a happier time!

Besides the quartz veins referred to, there are to be found in the bottoms of ravines and mountain glens alluvial or placer deposits of gold in considerable quantities. It has been stated that Don Vicente Guillem, jeweller of Holguin, with a single day laborer, obtained from these deposits gold sufficient for the requirements of his workshops.

Mines of various other minerals exist in Cuba, of which more than a brief mention need scarcely be made. Sixty kilometers distant from Santiago de Cuba, there is a group of ten mineral sites spread over an area of some 4,000 acres, the property of Don Julio Aurich, the mineral from which contains 34 per cent. of iron and 28 per cent. of manganese; these deposits are not worked. The mineral limonite (hydroxide of iron) is found in various deposits disseminated in Baracoa, where it has been discovered in strata in the ridges bordering the seashore.

Chrome iron is also to be found in the same district of Baracoa, where three mining claims have been taken up. The analysis of the mineral from the Valhourat Mine, made in the Paris School of Mines, showed the presence of chrome

oxide to the extent of nearly 58 per cent. Other mines of this mineral have been located at Mayari and at Sagua de Tanamo, in both of which localities it is very abundant. In Bayamo, in the precinct of Vavecito, there is a tract of 84 hectares (170 acres) of lead ore, and two other sites of this mineral in the same vicinity show veins of some 50 centimetres width, an analysis of which indicated the following:

| | Per Cent. |
|---|---|
| Lead | 46 |
| Zinc | 14·34 |
| Silver, per ton | 19 oz. |
| Gold, per ton | 3 oz. |

Of this mineral specimens were shown at the Chicago Exposition.

In the district of El Cobre, precinct of Sevilla, there is a deposit of argentiferous lead covering some 150 acres. The analysis shows the following:

| | Per Cent. |
|---|---|
| Lead | 45·73 |
| Sulphur | 16·45 |
| Silica | 10·38 |
| Silver | 0·39 |

Of this class of mineral sites numerous mining claims have been taken up, all of which remain unworked.

Of asbestos, two mining concessions have been granted at Mayari, both covering 120 hectares (300 acres). This mineral also appears in abundance at Holguin, in the Nuevo Potosi gold mine, where it is found in fibres 20 centimeters long.

Of guano, immense deposits exist in the caves of Cuba. In one cave of the Cantivar group, on the south coast of Santiago de Cuba, the property of the Guimera Company, there is a deposit of from 4,000 to 5,000 tons, and the other caves are estimated to contain fully 70,000 tons. This company has built a railway to handle the product, which has been sold in New York at a price of $7 per ton. Its cost for labor, carriage and transportation was figured at $6.15 per ton.

An analysis of this guano gave the following:

| | |
|---|---|
| Water | 35·75 |
| Potash | 0·05 |
| Ammonia | 0·55 |
| Phosphoric acid | 19·60 |
| Phosphate of lime | 42·98 |

The granites and marbles of Cuba have also been worked to a limited extent. In the adjacent Isle of Pines, off the southern coast of the Province of Havana, the quarrying of some remarkably fine marble, both white and veined, was undertaken, and the product was regarded by experts as equal in quality to that of Carrara and of Mexico; but the enterprise failed almost in its incipiency for want of laborers, as well as of means of carriage and of transportation to market.

CONCLUSION.—When it is remembered that in the Island of Cuba, where the production of sugar reached, in 1895, the fabulous amount of 1,100,000 tons, and where nevertheless, this industry became ruined; where only a fifth of the available land has been turned by the plough and the other four-fifths remain fallow, the fertile ground untouched by seed and given over to nature; when all this is considered, it is not at all astonishing to find that the mining industry has been unable, even with intelligent and earnest effort, to utilize the incalculable wealth beneath the soil.

There, where the mines are all of them at but a short distance from the coast, and from havens offering easy means of shipment; where numerous inlets, streams and other water ways afford abundant facilities for transit; where neighboring woodlands yield plenty of timber for building and other purposes; where the rigors of winter are never felt, and where snow is not present on even the highest mountain peaks; where the heat of the tropics is mitigated by cooling breezes from the ocean and where, in short, nature appears to have fairly poured its stores into the hands of men, there neither immigration nor capital take part, though neither would have remained indifferent to such attractions had there been an assurance of aught else than that, in the midst of all these natural resources, a due recompense for energy and effort could not be had.

What Cuba has lacked and still is lacking, is that which is the condition precedent to any development of population and of wealth; a condition of political stability, one with which the people are in harmony, which affords to the citizen, to the immigrant and to capital, freedom and security.

NEW YORK, 72½ Irving Place, March, 1898.

## APPENDIX.

The mining claims located in the island of Cuba up to 1891 were as follows:

| | | | | |
|---|---|---|---|---|
| Iron | 138 claims, | covering | 7,737 | hectares.* |
| Manganese | 53 | " | 4,015 | " |
| Copper | 5 | " | 1,160 | " |
| Gold | 5 | " | 232 | " |
| Asphaltum | 1 | " | 60 | " |
| Zinc | 3 | " | 99 | " |
| Lead | 2 | " | 166 | " |
| Quicksilver | 2 | " | 27 | " |
| Chrome iron | 1 | " | 56 | " |
| Coal | 2 | " | 115 | " |
| Antimony | 1 | " | 60 | " |

* A hectare is equal to 2·47 acres, approximately 2½ acres.

Following is an analysis of the Juragua iron ore:

| | Per Cent. |
|---|---|
| Iron peroxide | 95·15 |
| Silica | 1·90 |
| Carbonic acid | 0·98 |
| Alumina | 0·55 |
| Lime | 0 67 |
| Magnesia | 0·15 |
| Manganese oxide | 0·50 |
| Sulphur | 0·07 |
| Titanium | 0·03 |
| Organic matter | 0·00 |
| | 100·00 |

Manganese was exported as follows:

| | Tons. |
|---|---|
| 1888 | 1,942 |
| 1889 | 704 |
| 1890 | 21,815 |
| 1891 | 9,847 |
| Total | 34,308 |

An analysis of the ore from the Sigua copper mines gave the following result:

PER CENT.

| | | | | | |
|---|---|---|---|---|---|
| Copper | 48·70 | 41·32 | 40·78 | 47·31 | 48·31 |
| Iron | 0·70 | 3·46 | 4·75 | 2·35 | 2·74 |
| Sulphur | 3·88 | 4·21 | 5·28 | 0·88 | 1·34 |
| Silica | 25·13 | 31·42 | 33·28 | 28·37 | 27·38 |

An analysis of the ore from the manganese mines of San Luis showed the following:

PER CENT.

| | | | | |
|---|---|---|---|---|
| Manganese | 46·130 | 46·03 | 47·37 | 46·70 |
| Iron | 2·986 | 2·840 | 2·62 | 5·89 |
| Silica | 10·490 | 9·580 | 8·53 | 13·38 |
| Water | 6·614 | 6·743 | 7·35 | 11·34 |

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## DISCUSSION.

MR. E. V. D'INVILLIERS:—The very interesting paper just read is almost too general in its statements to be subject to discussion; but it appears to me that more stress might have been laid on the really excellent deposits of specular iron ore and manganese in the province of Santiago de Cuba, from which very large shipments have been made to the United States. Of course, during the distress consequent upon the present military operations, the exploitation of these deposits has been largely confined to the companies already established there, the chief of which are the Juragua and Spanish-American Companies.

The Sigua Iron Company, whose mines and plant lie about twenty miles east of the town of Santiago de Cuba, is now in the hands of receivers, and has not proved a commercial success since its incorporation in 1890, the ore deposits soon becoming too lean to warrant profitable shipments.

Why this is so it is somewhat difficult to say, and there is still an undercurrent of hope, if not of belief, that additional investigation on other portions of their large estate of some 40,000 acres will lead to the location of larger and better deposits of commercial iron ore. Indeed, but for the present war in Cuba steps might have been taken before

this to thoroughly prospect this property, and as the company owns such a large acreage of land covering the same range as that which has produced such large quantities of ore at the mines of the two other companies, it would seem not unreasonable that such development might lead to satisfactory results.

An unusually large number of experts, furnacemen and miners have visited and reported favorably upon this property, both prior to the purchase of the estate in 1890 and since actual operations were begun, and it seems strange that the attractive surface outcroppings should not have yielded a more stable and higher grade deposit of ore.

In this connection it might be stated that the Juragua Company has also passed through its periods of great uncertainty as to an ore supply, and that some of the richest and largest lenses of ore they have obtained showed absolutely no surface outcrop.

All the ore mined from this range, extending for about twenty-two miles east of Santiago de Cuba, is a red hematite of excellent quality, furnishing an ore with over 60 per cent. of iron and well suited for the manufacture of Bessemer pig.

As before stated, the manganese deposits to the north of Santiago de Cuba, at El Christo, as well as the old Cobre copper deposit to the west of the town and bay, are well worthy of mention and further examination. The reference to coal in Señor Cabrera's paper is of the first importance to the future of Cuba; but as yet I do not think its commercial character and occurrence have been sufficiently established to merit its recognition as one of the staple industrial products of this beautiful island, so rich in its varied natural resources, climate and soil, but so unhappy in its political government and history.

Prof. F. Lynwood Garrison:—In view of the probable cessation of Spanish rule in Cuba with a subsequent indirect or direct government under American influence, the paper by Mr. Cabrera is peculiarly appropriate at this time, and, although he treats the subject in a very general manner, it contains a number of interesting statements which deserve

careful consideration. When we remember it was the greed for gold that underlaid and gave the strongest impetus to the original Spanish exploration and colonization of the American Continent and its adjacent islands, it is certainly remarkable that, after centuries of settlement and civilization, so little is known of the mineral resources of the interesting island of Cuba, located on the very threshold of our great commercial and manufacturing centres.

That these mineral deposits are of considerable importance and value there can be but little doubt, but it is well to remember, in this connection, the tendency of the human mind to exaggerate the unknown, the hidden and buried wealth of an undeveloped mineral territory. This disposition—the essence of speculation—is latent in the minds of even the most conservative and careful men, and is one of the most difficult tendencies a careful mining engineer has to overcome in order to arrive at a safe and fair estimate of the undeveloped mineral resources of a new country. Nothing in the history of mining enterprises is more common than an over-estimation of their commercial value, and nothing is so disastrous to the country itself and to a healthy growth of its legitimate mining and metallurgical industries.

In the present instance it is well to accept with due conservatism any statements relative to the unknown or undeveloped mineral deposits of Cuba. Doubtless many localities will be found to be very rich, but it does not follow that they will all prove commercially remunerative. The value of an ore deposit depends not so much upon the inherent richness as upon a variety of economic conditions affecting its availability in reference to transportation, supply and quality of labor, fuel, timber, etc.; all these and other factors must be carefully considered if we are to develop successfully a mineral deposit of any description, however rich and wherever located.

During the reconstruction days, after the close of the present war, nothing possibly could be more disastrous to a healthy and successful development of Cuba's mineral resources, or, in fact, any of its latent wealth, than a boom

and an era of speculation. Fictitious values would be created, the money of innocent and confiding investors would be squandered, dissipated, and the country obtain an undeserved bad name, not soon to be eradicated.

The first observations of any value upon the geology and mineral deposits of Cuba were those of Alex. von Humboldt, some fifty or more years ago. Since his time there have been few publications upon the subject, and, as far as I know, none of much scientific merit, and few of practical value.

According to Humboldt, nearly four-fifths of the island is low and its surface covered with "secondary and tertiary" formations, through which granite and other eruptive rocks protrude. The highest elevations are in the southeastern portion, where a ridge known as Sierra del Cobre reaches an altitude of some 7,500 to 8,000 feet. He states that the central and western parts contain two formations of compact limestone, one characterized by the presence of a sandy clay, and the other by gypsum; the first he believes to be Jurassic. East of Havana, he states, the secondary (*sic*) formations are traversed by syenite and other plutonic rocks; on the southern, as well as in the northern side of Havana Bay, jurasic limestone is found. Going south, towards Gla and Guanabacoa, no syenitic rocks are found, the entire surface appearing to be serpentine. This latter rock is much fissured, is of a bluish-brown color, covered with manganese stains. Near Guanabacoa, serpentine is found traversed by quartz veins, amethyst, chalcedony, etc. He says that he could find no evidences of gray argentiferous copper, commonly reported as occurring in this formation. Petroleum exudes at this locality through fissures in the serpentine. It also occurs with other bitumens near Havana and at Holguin and Mayari in Santiago de Cuba.

I give a few of these observations of Humboldt's for what they may be worth. In more recent years, with the exception of the copper deposits at Cobre, as far as I am aware, the only important developments have been in the iron ores and the manganese deposits of Santiago de Cuba Province.

The copper mines of Cobre appear to be among the first,

if not the very first, of the mineral deposits of Cuba that were worked to any extent. It is supposed they were originally developed in 1524 by the followers of Velasquez, and in 1550 were operated by a German named Tezel. Some of the shafts sunk in these deposits reached a depth of several hundred feet when operations were abandoned some few years ago. This would tend to show that the deposits must be quite extensive and possibly rich. The low price of copper ore compared with twenty years ago, together with the inherent difficulties incident to successful mining in Cuba have doubtless led to their abandonment. Iron, manganese and bitumens (asphalt, etc.) will probably be the products most advantageous and profitable yielded of Cuba in the near future, peace and good government being once assured and maintained. Let us earnestly hope that the day may not be far off when the mineral riches of this unfortunate and stricken land will respond to the talismanic touch of capital and energy, that its rocks may pour forth their treasures to the benefit of mankind.

## CHEMICAL SECTION.

*Stated Meeting, Tuesday, December 21, 1897.*

## THE TECHNOLOGY OF CALIFORNIA BITUMENS.

BY S. F. PECKHAM.

The late publication of a paper, in which Prof. C. F. Mabery describes certain researches upon California petroleum, leads me to put on record what has been done upon the technology and chemistry of California petroleum in the thirty-two years that have elapsed since 1865.*

Prior to that date a reconnoitering party, accompanied by Prof. Benj. Silliman, Jr., had visited Southern California and had examined the deposits found in the valleys between Los Angeles and Santa Barbara. On his return to the East, Pro-

* C. F. Mabery, *Am. Chem. Jour.*, **19**, 796.

fessor Silliman made reports, based largely upon personal opinions, that were very widely circulated, but which, subsequent events proved, were based upon erroneous conclusions. A potent factor in the formation of these opinions was an examination of samples of oil, made by several distinguished chemists, which samples were afterwards proved to have been grossly falsified.*

Meantime, two companies, with vast resources on paper, purchased two large tracts of land and equipped and sent out to Santa Barbara and Los Angeles counties a corps of superintendents and engineers who were expected to develope a petroleum region that should rival that of Pennsylvania. The California Petroleum Company operated on the Ojai Ranche, north of Ventura; the Philadelphia and California Petroleum Company operated on the Simi, Las Posas and San Francisco Ranches, farther east; in the cañons of the Sulphur Mountain the Hayward Petroleum Company and Stanford Brothers were obtaining petroleum from pits and tunnels, and in the mountains west of the San Fernando Pass several parties were obtaining dense petroleum or light malthas in like manner. A small refinery was in operation on the San Francisco ranche, but the larger part of the oil produced was obtained from the cañons of the Sulphur Mountain, and was sent up the coast to refineries on San Francisco Bay.

During the summer of 1865 Drs. John Torrey and C. T. Jackson had visited the Ojai Ranche, and had made a report that to some extent confirmed the statements made by Professor Silliman. The last-named gentleman had also made experiments in Boston upon some of the "surface oil," so called, from Santa Barbara County. The oil or maltha was obtained from the Ojai Ranche, and when "cracked" yielded a distillate equal in volume to about 60 per cent. of the crude maltha, that when treated was pronounced a fair quality of burning oil.

In June, 1866, I made a reconnoisance of the region and prepared a report for the State Geologist of California, in which I showed that, in the ten months preceding, 2,448 barrels of

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* B. Silliman, *Am. Jour. Sci.*, II, **39**, 341; S. F. Peckham, *ibid.*, **43**, 345.

crude oil had been shipped to San Francisco, while the remainder of 7,000 barrels was allowed to run to waste. Very little merchantable oil was made from this crude. I took a number of samples with me when I left the Pacific Coast, and I subjected them to a series of experiments, the results of which may be summed up as follows: Distillation under pressure produced a fair yield of illuminating oil, which had a fine appearance but did not burn well. There was also a fair yield of lubricating oil of good quality. I also made an ultimate analysis of some of the California oils, and showed that they contained nitrogen and sulphur, and that the percentage of hydrogen was low.

My conclusions were thus stated, that "the best refined petroleum that I have made, either in California or at the East, as also the best that I have seen from other sources, fails to produce a light of such intense whiteness as the best refined Pennsylvania oils. It is my opinion that this difference is due to admixture of the 'benzole' series, or, perhaps, some other, containing a large amount of carbon in proportion to the hydrogen, in such quantity as to render the combustion incomplete, and thus produce a yellow flame."

The reports that I made to the State Geologist of California were unfortunately involved in the catastrophe that overtook the survey, and were not published until 1882, and then in a very limited edition, as Professor Whitney expressed it, "to furnish copies for the learned societies." In these reports I insisted that Southern California had veritable oil interests; that the crude oils were totally unlike those of Pennsylvania, yielding peculiar products of manufacture, and that no more inviting or promising field for chemical and technical research could be found than these bitumens present. In closing my last report (January, 1871) I made use of the following language, "The vast accumulation of the raw material in the southern counties, which though proved of but little value in its application to purposes and processes at present well known, is, nevertheless, an immense storehouse of material force, which only needs to be studied to be found of the greatest value as a source of fuel, if nothing more. It must constantly be borne in mind that this

variety of bitumen is essentially a new substance of unknown applications, which may be discovered either by research and comparison with other and better-known varieties or by the longer, more laborious and expensive process of empirical experiment." Professor Whitney was so far impressed with the importance of these facts that, during the last year of the Geological Survey, plans were perfected by which I was to spend a couple of years in the laboratory of the University of Berlin in conducting these researches. These plans were also involved in the wreck of the Geological Survey.*

For a number of years California bitumens attracted little attention. At the time I prepared the report on petroleum for the Tenth Census of the United States, I could not convince Gen. Francis A. Walker that there were any petroleum interests in Southern California that would warrant the expense of an investigation and report. In this conclusion he was mistaken, as at that time a large number of productive wells were in successful operation in Ventura County.

About 1890 or 1891, the different interests in the neighborhood of Santa Paula, Ventura County, consolidated into the Union Oil Company, of California. This company built a refinery at Santa Paula, and soon after called Dr. Frederick Salathé to assist them in the technology of the various oils that were received at the refinery from the different wells in the vicinity. The Pacific Coast Oil Company, which was operating farther east in Los Angeles County, always had an advantage in the business of refining, inasmuch as their crude oil was lighter in specific gravity and yielded a larger product of light distillates, which commanded a more ready sale than the heavy ones. Their refining had always been done at Alameda Point, in San Francisco Bay, to which place the crude oil was shipped in tank cars.

Dr. Salathé had entered upon his work at Santa Paula with a laboratory well supplied throughout except in one particular —there was no gas in that part of the country, and alcohol and gasolene were poor substitutes for gas, which has become

* S. F. Peckham, "Reports Geological Survey of California," Geology, ii, Appendix, 49-90.

almost an absolute necessity with modern methods and apparatus. His technical apparatus left nothing to be desired. He had also entered upon his work with the understanding that he could convert a large part of the California bitumen into benzole, and thus inaugurate a profitable technology. I have been informed that the Pacific Coast Oil Company had had their crude oils fractionated with results that showed a large proportion of the series $C_n H_{2n+2}$. Dr. Salathé professed to have reached similar results with the Santa Paula oil, and to have solved the same problem that he had solved when he converted Pennsylvania petroleum into benzole.

There were other problems to which Dr. Salathé gave his attention. He had extracted the bitumen from the Turrellite of Texas and called it Lithocarbon. It proved to be a sulphur bitumen. He had treated the asphaltic residuum of California petroleum with sulphur and called the product Petrocarbon. He also oxidized one of the California distillates for use as a basis of printers' ink and called that Linolith. He re-invented the use of caustic lime instead of caustic soda in the treatment of distillates, a process first used by Selligue about seventy years ago. He also invented a process for treating lubricating oils by diluting them with naptha, and then, after treatment, distilling off the naptha. After Dr. Salathé had been with the company about a year and a half and had applied for patents on all of these processes, I was asked to visit Southern California and help Dr. Salathé get these numerous patents through the Patent Office. After I had been engaged in this work for some time I was informed by Dr. Salathé that he had discovered that the crude oils and their distillates contained nitrogenous basic oils, and we at once set about contriving methods for removing them from the distillates, thereby improving the products in various ways. After a time Dr. Salathé left the employ of the company and I was placed in charge of the refinery, in addition to other work.

The refinery was, for the most part, one that had been originally set up in Pennsylvania and had been taken down, carried to Santa Paula and reconstructed. It was at first operated profitably on very crude and cheap products, but it was found

wholly inadequate to meet the demands of a market rendered fastidious by the highly-finished output of eastern refineries, and especially when required to treat such a variety of materials as finally passed through it. It was also used as a loading station for a large amount of heavy fuel oils.

The crude oils used in the refinery were of different colors, from green to black, and of specific gravities ranging from 20° to 35° B. These oils were distilled to a variety of residuums that differed in consistency from heavy oils or tars to brittle solids. There were made five grades of solid asphaltic residues, a dense paving flux that would scarcely flow, a more fluid paving flux and a reduced green oil called "skid oil," that was used to grease the skids in the lumber districts up the coast. From the distillates from these residues were made gasolene, naphthas, gas oil of 40° B., an oil of 28° B., and several grades of lubricating oil, light and heavy, treated and untreated.

The three stills were connected with condensers that were cooled in one box, a very bad arrangement. To make such a variety of residuums, reduced oils, etc., in three stills required constant changing and cleaning with an enormous loss of time, and the omnipresent difficulty occasioned by soiling the product of one distillation by that of the previous distillation. It was also impossible to so perfectly clean the stills, agitators, tanks and tank cars that the second charge was entirely free from the previous charge, yet some very good oils were made. The engineers of the locomotives of the Southern Pacific Railroad frequently filled their cans with our oil, declaring it was very much better than that which was provided them from some eastern refinery, and the Superintendent of Motive Power admitted the superior quality of our oils, but declared his inability to use them, as he was not the purchasing agent.

The gasolene and naphthas, while possessing a very different odor from articles of the same name and density made from eastern petroleum, were not found to be practically different when applied to the same uses. No burning oil was made. One batch was turned out without regard to cost as an experiment. In this instance the crude distillate was carefully washed with dilute sulphuric acid to remove basic oils. It was

then carefully treated with oil of vitriol and caustic soda and finished by distillation. It was beautifully colorless and brilliant, like the oils I had made thirty years before. Some of the best illuminating oil made from eastern petroleum in the Los Angeles market was obtained, and the two oils were filled into two new lamps with carefully-trimmed wicks. They were made as nearly alike as possible, and the combustion was made as nearly as could be identical. The eastern oil burned to the last drop and left the lamp dry. The California oil burned well for a time, then the flame became yellow, the wick crusted, and at last the flame was extinguished with the oil only about half burned. It was sought in the above-described experiment to make as good an oil as could be made from California crude oil without regard to cost. The result of the experiment was conclusive so far as Santa Paula oil was concerned; it afforded no encouragement whatever for the manufacture of illuminating oils from California crude, and confirmed the opinion that I had ventured years before and expressed, as above quoted.

I have in my possession a sample of the burning oil that I made from pressure distillate in 1867. It has become bright yellow in color, and a sediment of a deep orange color has gathered in the bottom of the bottle. The cork has been bleached for a long time, but the odor and density are unchanged. The change of color went forward when, for a number of years, the bottle was packed in a box excluded from light. In his report upon petroleum to the United States Census of 1890 the late Joseph D. Weeks stated that some of the wells near Newhall, Los Angeles County, furnished an oil that contained the paraffine series of hydrocarbons. Perhaps this opinion was based upon a report made by an unnamed chemist, whose results I was shown while in California, and who claimed to have isolated Warren's paraffine and isoparaffine groups, olefines and benzoles from the oils obtained by the Pacific Coast Company. I have myself obtained from these oils the esters of the nitrogenous basic oils, but the accidental loss of my specimen prevented me from investigating it further.

Soon after I reached California, in 1893, Dr. Salathé showed

me what he claimed was crude paraffine from one of the wells in the Torrey cañon. He dissolved some of the material in naphtha, filtered the solution, and, evaporating the naphtha, obtained a white, wax-like solid. He claimed that this experiment proved the existence of paraffine in the Torrey cañon crude oil. I afterwards visited the Torrey cañon and was given a mass of a dark-brown, wax-like substance, which I was told was the other half of the mass given Dr. Salathé, and that the whole was taken from the sucker rods of one of the wells. I have since examined this material sufficiently to prove that it does not consist of any form of paraffine, but is an unsaturated hydrocarbon, readily combining with sulphuric and nitric acids. It is no doubt a solid olefine or naphthene.

A great variety of lubricating oils were made of various densities. As already stated, a reduced green oil was prepared and sold under the name of "skid oil." All of the lubricating oils prepared from green crude oil were superior to those obtained from brown oil, they in turn being superior to those obtained from black oil. The causes of these differences I have not been able to fully demonstrate, but am convinced that they are found in radical differences in the crude oils. The crude black oils, without regard to density, appear to undergo more rapid decomposition than the green or brown oils, and the crude heavy distillates from black oils also appear to be less stable. Immediately upon the discovery of the presence of the basic oils I urged Dr. Salathé to remove them from the distillates and see what the effect would be upon the finished product. Accordingly, we washed 100 barrels of light lubricating distillate with 100 pounds of oil of vitriol, made into a 10 per cent. solution. The result was the complete saturation of the acid, the solution becoming brown, and tasting bitter instead of sour. The solution acquired a strong odor of a cow stable, indicating the presence of hippuric acid, which is a benzole product. On drawing off this solution it was followed by a tarry mass, nearly solid, very adhesive, and possessing great tenacity. A second treatment with dilute acid gave a solution that was strongly acid. After thorough washing with water, the oil was treated with the ordinary 5 per cent. of oil of vitriol,

which was accompanied with a copious disengagement of sulphurous oxide gas and a quantity of "sludge acid" having the usual appearance. The oil was finally treated with air-slacked lime, and finished in the settling tanks. Some of the heaviest lubricating distillates were finished in the still as reduced oils, and others were diluted with naphtha and treated, furnishing highly-finished products of fine quality. On pushing our applications for patents through the Patent Office, we found we were using processes already in use in the Scotch paraffine oil industry, although we were not aware of the similarity existing between both the materials and methods.*

A number of barrels of the acid solution of the basic oils were introduced into an agitator, an equal quantity of naphtha added, and the acid neutralized with a strong solution of caustic soda. As the naphtha was steam distilled, we supposed we could separate it from the basic oil by steam, but in this we were in error. The oils held about one-third of their bulk of naphtha when treated in a still with a steam coil through which steam was held at a pressure of 100 pounds. The mixed solution of three parts of oil and one part naphtha was put into a still heated directly and distilled to coke. The first naphtha that came over contained pyridin, but the amount of basic oils continued to increase until the sixth 5 per cent. was free from naphtha. These basic oils were all very heavy. They were at first of a brown color, then they became cherry red, and then brown again. The last that came over were heavier than water, through which they sank in drops like shot. A portion of the cherry-red oil of the proper density was found by Dr. Salathé to be nearly pure chinolin, which yielded some very fine purples and violets on silk. These oils readily dissolved in acid; the coke also was partially soluble in hydrochloric acid. From these acid solutions the hydrates of the basic oils were precipitated by caustic soda in cream-colored flakes. When these flakes were gathered on a filter they soon turned brown, and in time they completely evaporated at the ordinary temperature of the atmosphere.

The acid tar was soluble in alkaline solutions, from which

* S. F. Peckham, *Am. Jour. Sci.*, iii, **48**, 250.

it was again precipitated as a brown powder. The acid tar from green oil was of a brown color rather than black, and was also more nearly fluid than that from black oil.

All of these facts, which have been accumulated through many years, confirm the prediction that I made in 1871, which I have quoted above. It was also confirmed by the results of a fractional separation that I made a year ago, which results are stated in a paper which was read February 5, 1897, before the American Philosophical Society. This prediction is also confirmed by the results detailed by Professor Mabery, as he shows that the constituents of California petroleum are not to any appreciable amount paraffines, but belong to series having the formula $C_nH_{2n}$. I am convinced from the results of my own fractionation that a proportionately very large amount of benzole and its homologues are present, which fact accounts for the difficulty which has been experienced in all the attempts that have been made to prepare illuminating oils of good quality from California crude petroleum.

The polymerization of these oils, and the rapid conversion of both oils and tars into maltha and asphaltum, is, no doubt, due more largely to the presence of the unstable nitrogen and sulphur compounds than to the presence of any series of pure hydrocarbons. To what extent it is advisable to remove these compounds of nitrogen and sulphur from commercial products is, of course, a commercial as well as a technological problem. So, too, is the question as to how far these oils can be profitably made a source of pyridin and other benzole compounds.

# ELECTRICAL SECTION.

*Stated Meeting, January 11, 1898.*

## THE OVERHEAD LINE AND GROUND RETURN CIRCUIT OF ELECTRIC STREET RAILWAYS.

BY DAVID PEPPER, JR.
Member of the Institute.

On the proper design and careful construction of the line and ground return circuit depends, to a great extent, the satisfactory and economical operation of an electric railway. The practice of the present time is the result of costly experience. Within the last few years there have been great advances made in the character of the outside work, and the materials entering into the construction have been greatly improved. In the early days of electric street railways, the importance of the line, and especially the return circuit, was very little thought of. The cheapest form of construction that would cause the cars to move at all was usually installed. Managers now find that it is very bad economy to attempt to save money on their outside work. The direct loss in receipts and prestige, owing to failure of the outside construction, is very great; and the loss in power, owing to poorly proportioned or poorly constructed work, is a constant loss. The overhead trolley line should have sufficient strength in all its parts not only to hold up the dead weight of the trolley wire, but to resist all sudden and heavy strains caused by blows from trolley poles, the falling of outside wires upon the trolley wire, and the breaking of the trolley wire.

The trolley wire in city work is usually supported on iron poles placed, about 125 feet apart, in pairs on opposite sides of the street. These poles are usually made of from two to three sections of heavy iron pipe, telescoped into each other about 18 inches, and the joints swedged while hot. On straight line construction, unless the street is very wide, poles 28 feet long and weighing from 700 to 750 pounds are used.

On wide streets and light curves, and with extra heavy trolley wire, poles from 900 to 1,100 pounds are used. On heavy curves the poles weigh 1,300 pounds and over. In setting these poles, great care must be taken that they are set in such a way that there is no give at the base of the poles. If the poles give after the strain is put on them, it will loosen up the entire line, especially at curves and special work, and cause a great deal of trouble in repairing. The lighter weight poles, when set in fairly good ground and with a curbstone in front, should be placed in holes from 18 to 20 inches in diameter, and from 6 to 6½ feet deep, and set with a rake to allow for straightening when strain is placed on them. The concrete used should be made of 1½ bags of improved natural cement, one barrel of sand and sufficient stone to fill the hole. The sand and cement should be made into a thin mortar, mixed with the wetted stone, turned at least three times, and the mixture then rammed in the hole in six-inch layers. The concrete will be worthless if it is not properly rammed, or if there is too much or too little water in it. For pull-off poles, and where there are heavy strains, two bags of cement should be used and the poles set in larger and deeper holes.

In cross suspension work, the span wires are usually secured to poles with wrought iron bands, and one or two mechanical insulators are placed in each end of span, near pole. In the early construction, silicon bronze and solid steel and iron wires were used for the spans. It was found that the tensile strength of these wires, if they were scratched or kinked in any way, was greatly reduced, and that their composition was somewhat uncertain. Seven-strand galvanized steel cable is now used, $\frac{5}{16}$ of an inch in diameter for ordinary single-track suspension and pull-offs, and $\frac{7}{16}$ of an inch on long spans and $\frac{4}{0}$ trolley construction.

Care should be taken in placing spans to allow for the proper sag when the suspension device is sprung on the span wire. If the span is tight, say having a sag of only 8 inches in 35 or 40 feet, there is great strain put on the pole. If the sag is too great, the line will look bad and violent vibrations will be set up in it every time a car passes. The

exact tension of the spans is a matter of skill on the part of the man putting them up.

The insulators used in the span wire are of many types and makes. The insulation is usually hard-rubber compound or one of the many special compounds made for this purpose. There is a heavy strain sometimes placed on these span wires, and the constant vibration will quickly find any imperfections in the insulating material and cause either a break in the wire or a leak to the pole. Those forms of insulators involving screw connections are not usually as strong as those of rigid type; and, as the take-up is seldom if ever used in practice, it is better economy to use two solid strain insulators instead of a turnbuckle.

In many cases where the track is on the side of the street, a single line of poles is used and the trolley wire suspended from a pipe bracket, which is usually trussed in some manner. A plain bracket gives a rigid line, which causes a great deal of wear and tear. To overcome this rigidity, brackets are often made so as to rise a little under the pressure of the trolley, or the hanger is secured to a span wire under the bracket. Bracket construction, unless securely guyed, is much more liable to serious damage than span construction, owing to the lack of strength latteraly, if the wire breaks or if the trolley pole comes off and strikes the bracket.

We now come to the method of actually suspending the trolley wire. There is sprung on the span wire a casting of malleable iron or bronze, containing an insulated bolt of from $\frac{5}{8}$ to $\frac{3}{4}$ of an inch in diameter. This insulated bolt is sometimes placed in the casting and the top screwed down. In others it is contained in the body of the insulating material within the bell. The latter form is probably the best, owing to the much better protection given the insulating material from blows from the trolley wheel and from the weather. The principal advantage claimed for the other form of insulated bolt is that only one portion has to be thrown away in case of failure to work properly.

At curves, the trolley wire is suspended by special pull-off hangers placed sufficiently close to prevent sharp bends

in the trolley wire. The usual distance is from 6 to 10 feet, depending, of course, upon the degree of curvature. Where pull-off wires cross the straight line trolley wire, they should be secured to it the same as at the spans. The pull-off wires should all come together in an extra heavy strain insulator at the pull-off pole. It is well at this point to have a turn-buckle capable of tightening the entire series of pull-offs. Care should be taken in all pull-offs and special work to have each and every pull-off wire insulated from its neighbor, in such a way that in case of a failure of the pull-off insulation from the trolley to the pull-off wire, only one wire will be alive. When this precaution is not taken, it causes a great deal of trouble in locating the leak in a complicated curve.

In iron pole construction, the insulation is an important item, first, to prevent leakage to the trolley pole, which not only causes a steady loss but, perhaps, the shutting down of the lines, and also as a matter of safety to the men working on the live trolley wire. It is very disconcerting to a lineman working on a ladder or tower wagon to unexpectedly discover that the span wire, which he thought was insulated, is connected directly to the ground through the pole.

Probably one of the most important matters in trolley construction is the method of suspending the trolley wire from the hangers, and this is especially true on roads where the cars run at a speed exceeding ten miles an hour. The slightest obstruction on the underside of the trolley wire will cause the trolley wheel to leave the wire a short distance to come back again with a sharp blow. Each time the wheel leaves the wire there is an arc formed that takes off a small portion of the wheel or wire. If the obstruction is sufficient, the wheel will be thrown so far down from the wire that on its return it will miss the wire and go down the line striking span wires and special work, and straining every part of the overhead construction. This is one of the principal causes of trouble on the line. Probably one of the most satisfactory methods of suspending the wire is by using a bronze or composition ear, 15 inches long, with a groove of the diameter of the wire, milled in the solid of the

lower portion of the ear, the depth of this groove to be about the diameter of the wire. The extra portion of the metal is so proportioned that it can be securely hammered down on the trolley wire. The ear should then be carefully soldered, using soldering salts and solder; this, when properly done, makes a first-class job, but there is danger that the wire may be damaged by careless or unskilled workmen. Should the iron be so hot as to partially anneal the trolley wire, there is a very great reduction in tensile strength at the ear, and the wire may be so damaged that on the first strain it will draw out and break. Only the most skilful men should be entrusted with this work, as it requires care and skill that can only be obtained by practice.

To give a smooth under-running surface to the trolley wire, many devices have been tried. The trolley wire has been rolled in the form of the figure 8, and a mechanical clamp devised to hold the wire in place, giving, theoretically, a smooth under-running surface. Unfortunately the wire, in practice, is likely to be twisted slightly in the erection and at curves, with the result that the trolley wheel runs on the two loops of the wire, giving extremely unsatisfactory results. To overcome this trouble, the section of wire was modified to three points, instead of two, and this has been found to work much better. Another plan, of good promise for high speed work, was to take a four naught round trolley wire and with a special machine to press or mill a groove on each side of the wire, just above the diameter, to fit a clamp. This device answers very well, but it is somewhat difficult to repair work put up in this manner. Another class of suspension involves the use of metal below the trolley wire. Others involve the kinking of the trolley wire. Both of these last-named methods are open to serious objections for high-speed roads.

Another important part in the work is the joining of the trolley wire. This can probably be best accomplished by a long, hard-rolled copper sleeve, about 18 inches long, turned to a cone at each end and so arranged by boring and milling groves that the wires come out together in the middle

of the sleeve. The hole is then soldered and the surplus wire cut off. Another style, without solder, involves some form of clamping device within the tube, the inner chamber being larger than the bore for the trolley wire to enter.

In all special work, such as frogs, cross-overs and section breaks, care should be taken to choose that which gives a clear under-running surface. In high-speed work the tendency is to entirely avoid switches and to substitute for same two trolley wires, or cause the trolley to be lowered and placed on another wire on cars leaving the main line. At any speed above ten miles an hour, the chances are greatly in favor of the trolley wheel leaving the wire.

In the early days No. 6 to No. 4 B. & S. gauge wire was considered quite heavy enough for the trolley wire. It was soon discovered, however, that this was entirely too light, and for many years single naught hard-drawn copper wire was used. The tendency is strongly in favor, for standard city work, of the use of double naught wire. It has been proved by experience that the troubles from the breaking of the trolley wires are reduced to about one-third the number when double naught wire is used. If single naught trolley wire is drawn so tightly that the up and down vibrations only show for three or four poles, the wire is strained well up towards its safety limit, and will not stand a sudden and violent blow. The wire should be stretched so that in winter there will be a sag of about 10 inches in every 125-feet. This will make a considerably looser line in summer time.

In deciding upon the size of trolley wire, there are several other problems to be considered besides the tensile strength and freedom from accidents. In a net work of wires such as here in Philadelphia, the trolley wire is not usually depended upon as part of the feeder system, other than for six or eight cars on a single section. In suburban lines, with comparatively few cars, the question of using the trolley wire as part of the feeder system becomes an important one; and the difference between one naught and two naught trolley, and still more so between two naught and four naught trolley, will determine whether or not a heavy feeder will have to be run alongside of the trolley

wire. The cost of bare copper in the form of two naught or four naught trolley is considerably less per circular mil than the cost of a single naught trolley wire plus the necessary insulated feeder wire.

In designing any feeder system, the proposed conditions upon which the line is to be run should be very well known, and the line designed for economy of current and original investment for average load, with the provision made that on very heavy loads the voltage will not fall below 375 volts for a few moments. One of the causes of the failure of insulation on iron-pole construction is the effect of lightning discharges on the line, which greatly weaken and strain the insulators, even if they do not break down on the first discharge. To overcome this, it is usual to place one of the well-known and tried makes of lightning arrester at each feeder tap, providing it with a kicking coil, and being careful that there be as few bends as possible in the wire to the ground. The lightning arrester should preferably have a single naught tinned wire run down inside of the pole and connected securely to the return circuit and track. The mere grounding of a lightning arrester to a trolley pole set in concrete is not sufficient, as, even on a wet day, there have been cases known where the concrete acted as such a good insulator that there was a difference of potential of 475 volts from pole to track. On wooden-pole construction, the problem of insulating is very much simplified, as eighteen or twenty feet of wooden pole, properly painted, is probably as good an insulator as can be made. Wooden poles of sufficient weight and of first-class yellow pine, chestnut, oak or cedar, painted with a preservative compound at the butt and painted two coats of good paint, are as satisfactory as iron poles; and, in the long run, as well as in first cost, are a little cheaper. They will last about one-third as long as the estimated life of an average iron pole properly painted.

The limitations to the overhead trolley are now quite generally recognized. It has been found that it is difficult to efficiently transmit, by means of the ordinary form of trolley wheel, more than 150 amperes from the wire to the wheel without excessive sparking and loss. The speed at

which a trolley wheel will stay on the wire, through section insulators, special work and switches, is limited in good practice to not much over ten miles an hour. When the trolley stand and wheel are both designed for high speed and the line carefully constructed, it is possible to run on straight-line work at a speed of about thirty miles an hour. Beyond this speed the tendency to throw the wheel from the wire, owing to slight obstructions on the trolley wire, is very great. If the wheel leaves the wire at this speed, it is almost certain to either break the trolley pole or bring down a large portion of the overhead construction. It is for this reason that experiments have been and are being tried to substitute a fixed conductor near the ground with a large surface contact for the overhead trolley wire, for high speed and heavy currents.

A great deal of attention has recently been given to the matter of ground return. It has been found that the current on an imperfectly bonded track is very likely to come back to the station through water and gas pipes and on the lead covering of underground cables, setting up electrolitic action, which, in some instances, speedily destroyed the pipes. In bonding a track, the first thing to be considered is to get as low a resistance as possible at each joint. It is also necessary to have an assurance that the bond will remain in perfect condition for a long period of time and will stand the maximum current that will be called upon to go through a special piece of track. The actual cost of the material for bonding a track, with most modern systems of bonding, is a small item compared to the original labor of putting it in place and the cost of re-bonding the track within a few years, without taking into consideration the watts daily lost in the bond circuit. Few persons realize how low a resistance a pair of nine-inch girder rails have, and that every effort should be made to get the full benefit of this return circuit. The resistance of the rail is from six to seven times the resistance of the same section of commercial copper. Very few tracks are bonded more than one-fourth or one-third the carrying capacity of the rail. It has been proved in practice that the earth and fish plates are not to be depended on as part of the return circuit for heavy currents.

# THE CHEMISTRY OF HIGH TEMPERATURES.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the investigations of M. Henri Moissan, with the electric furnace.*]

[No. 1,953.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 1, 1897.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Moissan's investigations with the electric furnace, reports as follows:

The researches conducted by M. Henri Moissan, with the aid of his electrical furnaces, extend over a period of about five years, and have won for this distinguished chemist an additional title to take rank with the foremost exponents of scientific inquiry at the close of this century of science, so auspiciously inaugurated by the great discoveries of Gay Lussac and Sir Humphry Davy.

In preparing a report upon the work of the French chemist, your committee feels that it might well be content to pass in review those brilliant discoveries which have become universally known, and that it would scarcely be possible to refer to all the valuable and interesting results without making the report too voluminous.

At the same time, the committee believes that much of M. Moissan's purely scientific work has not been as generally recognized as it deserves to be, and, therefore, begs to present the following statement:

The application of the high temperatures attainable by means of the electric arc, for the purpose of producing physical and chemical effects, is by no means of recent date. Many important observations on the effects of electric heat were made already by Van Marum, at the close of the last century, and by Humphry Davy, the discoverer of the arc, at the beginning of the present one. In 1849 Despretz utilized the intense heat of the arc in various scientific investigations, and later

Pichon, Siemens and Huntingdon, Cowles, Heroult, Grabau, Borchers, Acheson, Willson and many others either suggested or realized the employment of the electric furnace for various industrial purposes.

In all these cases, however, the materials subjected to the arc were directly exposed to and permeated by it. But, while this may not be objectionable in many industrial processes, the presence in the arc of vapors of carbon and other substances emanating from the electrodes, and the attendant electrolytic action, constitute a set of disturbing influences which will generally complicate the results, and render them liable to lead to erroneous conclusions.

Guided by these considerations, M. Moissan endeavored to devise a furnace which would subject bodies to the highest temperatures of the electric arc under simple and controllable conditions. He has constructed five modifications of such a furnace, which are characterized by the following features:

(1) A furnace consisting of a block of lime, hollowed out, and provided with electrodes in such a manner as to maintain the arc above the substance. The cavity is lined with suitable materials.

(2) A furnace of fine-grained limestone lined with alternate layers of carbon and magnesia, the former on the inside. This construction permits the use of higher temperatures than the preceding one, and is well adapted for receiving crucibles.

(3) A furnace provided with a tube of refractory material, passing horizontally through the cavity. This arrangement affords a heated space, which is accessible from without, and protected from the action of any gases existing within the furnace. When desired, currents of gases or vapors can be passed through the tube while it is being heated.

(4) A furnace in which the tube is given an inclined position, which permits a continuous operation; the charge is introduced at the upper mouth, while the products are removed or flow from the lower one.

This model was employed for preparing large quantities of pure products in a short time.

(5) A furnace with a larger number of electrodes and arcs.

By this means a considerable space can be evenly heated, and large amounts of material treated in one operation.

By thus excluding electrolytic action, M. Moissan was enabled to investigate the simple heating effect of the current. The temperature ranged from 2,000° to beyond 3,800° C. While it is not possible to give exact figures for the highest temperature attained, an idea of the conditions may be formed from the description of some of the experiments. The currents employed varied from 35 ampères at 55 volts to about 1,600 ampères at 110 volts.

The results obtained by means of the electric furnace may be considered comprehensively under the following heads:

I. *A series of researches on the fusion and volatilization of refractory bodies.*

Various compounds and elements which are either infusible or non-volatile at the highest temperatures attainable by combustion were melted or vaporized when subjected in the furnace, Model 1, to an arc consuming 30 to 40 horse-power of energy.

Thus lime, magnesia, molybdenum, tungsten, vanadium and zirconium were readily fused, and lime, silica, copper, platinum, aluminium, boron, carbon and other refractory bodies volatilized.

Many of these bodies were obtained, either by fusion or sublimation, in a crystallized form.

By heating mixtures of several oxides a series of new double oxides was prepared.

II. *In a second series of experiments a number of reactions, which can be effected at the highest temperatures only, were made the subject of investigation.*

The carbonates of barium and strontium were without difficulty resolved into carbonic acid and the oxides. Those oxides which had withstood the de-oxidizing action of carbon at the highest temperature of ordinary furnaces were readily reduced by that element in the electric furnace; others, whose reduction by carbon in the wind furnace is difficult or incomplete, readily yielded their oxygen to the carbon under the action of the arc.

It was thus possible to obtain aluminium, silicon, the alkaline-earth metals, uranium, vanadium and zirconium. Moreover, manganese, chromium, tungsten and molybdenum were produced in the reguline state and in considerable quantities. Certain ingenious precautions were observed to prevent the metals named from combining with oxygen, nitrogen and carbon, and to remove the last-named element after a carbide had been formed.

As many of these products were for the first time obtained in the pure state or in much larger quantities than before, a careful study of their properties afforded innumerable new and interesting observations, and led to the revision of many statements published by former investigators.

The study of chromium and vanadium proved especially interesting. Titanium was found to be converted into the nitride when subjected to an arc produced by a current of 400 ampères and 60 volts, but to remain metallic when a current of 1,200 ampères and 70 volts was employed.

Reductions were also effected by substituting metallic reducing agents for the carbon, and interesting new alloys were thus prepared.

III. *The study of the three allotropic modifications of carbon constituted a third extended series of experiments.*

It is impossible here to do more than mention a few of the more important results.

The most important, perhaps, and the one which has become universally known, is that ordinary charcoal may, by means of the electrical furnace, be converted into diamond.

When molten iron at 3,500° is saturated with carbon and the mass then suddenly chilled on the outside, the enormous pressure produced in the interior will cause part of the carbon which separates to crystallize in the form of diamond. Both the transparent and the black (carbonado) varieties were thus obtained—the former in octahedra and cubes, as well as in fragments; the specific gravity of 3·5, the hardness and all characteristics corresponded to those of the native stone.

It is further shown that, at about 3,000°, under ordinary pressure, all the modifications of carbon are converted into

graphite, and various varieties of this (the ultimately stable form of carbon) were recognized and studied.

The reason for the infusibility of carbon under ordinary pressures was established to be due to the fact that it passes directly from the solid into the gaseous condition. Carbon was actually sublimed and the reactions of its vapor studied.

IV. *There yet remains to consider the investigation of several new series of crystallized compounds belonging to the classes of borides, silicides and carbides.*

M. Moissan has shown that these compounds, as a rule, have very simple compositions, and that, at the highest attainable temperatures, carbon, silicon, and boron generally form but one compound with another element.

The silicides, like Acheson's carborundum, possess extraordinary hardness; some, as those of boron and titanium, appear to be even harder than the diamond.

Of the metals, some do not combine with carbon; others while dissolving it at very high temperatures deposit it as graphite before they solidify. A very large number of metals, however, form definite, crystallized carbides.

These M. Moissan divides in two classes; those which decompose water at ordinary temperatures, as, for example, the carbides of the metals of the alkalies and alkaline earths, of aluminium, cerium, etc.; and those which do not react in this manner, and which include the carbides of chromium and titanium.

It appears that M. Moissan was the first to produce the crystallized calcium carbide in the electric furnace. He has also exhaustively studied the action of the various carbides on water. In a few cases, as with calcium carbide, there resulted a single hydrocarbon in a pure state; in others, mixtures of hydrogen with one or several hydrocarbons, such as methane, ethylene and acetylene. The most interesting carbides in this respect, however, are those of cerium and uranium. They were found to yield not only gaseous hydrocarbons but considerable quantities of liquid and solid hydrocarbons.

M. Moissan believes that analogous reactions play an important role in the formation of natural gas, petroleum and

other natural hydrocarbons; he has advanced a new and interesting theory in regard to this.

The above is but a meager resumé of the work done by M. Moissan with his electric furnace. The enormous number of new and valuable results obtained by him necessitated a selection. In studying the effects of extreme temperatures the French chemist has opened up a new and extended field to scientific research, and the harvest already reaped from it has greatly enriched our stores of knowledge in the provinces of chemistry, physics and geology. Innumerable practical applications suggest themselves, and not a few have already been realized.

As a conclusion, we wish further to state that the manner in which he has described, interpreted and summarized his experiments and his results cannot fail to incite others to follow the paths he has prepared, and lead them to further discoveries in this field.

In view of these facts, your committee takes pleasure in stating that the highest award the Franklin Institute can bestow could not find a worthier recipient than the author of these researches.

The Franklin Institute, therefore, awards the Elliott Cresson Medal to M. Henri Moissan, of Paris, France, for his work on the chemistry of high temperatures.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, December 1, 1897.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,

*Chairman of the Committee on Science and the Arts.*

# On the MOLECULAR CHANGES in CAST IRON CAUSED by VIBRATION.

[*Being the report of the Franklin Institute, through its Committee on Science and the Arts, on the investigations of Mr. A. E. Outerbridge, Jr.*)

Hall of the Franklin Institute,
[No. 1,910.] Philadelphia, May 5, 1897.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of Outerbridge's Investigations in the Molecular Physics of Cast Iron, reports as follows:

The work of Mr. Outerbridge, under consideration, has been so often and so fully described in the technical press, and in the papers herewith submitted by him, that an extended notice is unnecessary. In brief, certain deviations from the expected strength of test bars, made in connection with his work, led Mr. Outerbridge to make an investigation as to their previous treatment, and it was found that the only assignable cause for the increased strength noted was the fact that they had been, contrary to the usual custom, rumbled in a mill in order to clean them. Mr. Outerbridge followed up this observation with a careful and scientific investigation regarding the effect of vibration on cast iron, confined, however, to a limited range in the composition of the samples.

Many of his earlier results are given in the papers submitted by him. It is to be regretted that the later results, as well as some of the practical applications, cannot be laid before the Institute, as showing more clearly the decided value of Mr. Outerbridge's work. The principal result has been to largely upset some of the ideas generally held on the subject of cast iron, and where formerly it was considered essential that small or light castings must be protected from shock, it is now believed that they may be generally strengthened and relieved of their internal cooling strains by judicious treatment in this way.

Members of the sub-committee have made many experiments similar to Mr. Outerbridge's, for transverse strength, and they believe that where the proper conditions are observed there will be a decided gain in strength in almost every case, at times running as high as 35 or 40 per cent. increase in the rumbled over the unrumbled bar (some of these results are appended hereto). Many others have made similar experiments with the same results, both with high and low silicon irons.*

The fact that a certain molecular change takes place in cast iron in the course of time has been known and recognized by many persons for a long time, and that this change tends to relieve the internal strains and render the casting tougher has often been noticed and acted on, although in a very crude way; but, so far as this body has been able to learn, Mr. Outerbridge has been the first one to make a careful study of this subject and to note that the change may be hastened by impact, and the whole effect produced in a short time, and also to make a scientific study of the phenomenon. We believe great credit is due to him for the initial observation and the careful work dependent thereon. The results were first given to the public in a paper read

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* Dr. H. I. Hannover, Professor of the Royal Technical High School and Director of the New Danish Government Testing Laboratory, at Copenhagen, published an article on A. E. Outerbridge, Jr.'s "Researches on Molecular Changes in Cast Iron," giving in full the report of the Committee of Science and the Arts of the Franklin Institute, together with the table of tests made by the committee in the course of the investigation. In this table there appeared some clerical errors, which did not, however, affect the correctness of the conclusions.

Professor Hannover first discovered these errors, and alluded to them in a foot-note to his article, which appeared in the journal *Baumaterialienkunde* Nos. 11 and 12, page 181, July, 1897 to 1898.

In *Stahl und Eisen* (March 1, 1898), Prof. A. Ledebur gives the substance of Professor Hannover's paper, and shows by averaging the errors that they do not materially alter the result. He calls attention to an increase in strength of iron bars, due to mechanical treatment, noted in his "Handbook of Iron and Steel Melting." He says (p. 62) "I have given as the mean bending strength of cast iron—

| | | |
|---|---|---|
| Unworked | 25 kilograms | 1 sq. mm." |
| Worked | 29 " | |

W.

TESTS MADE BY SUB-COM. No. 1910, ON BARS 26 x 2 x 1—TESTED FLAT, 24 INCHES BETWEEN SUPPORTS.

| | | NOT RUMBLED. | | RUMBLED. | | PER CENT. INCREASE. | | | | NOT RUMBLED. | | RUMBLED. | | PER CENT. INCREASE. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date. | No. | Load. | Defl. | Load. | Defl. | Load. | Defl. | Date. | No. | Load. | Defl. | Load. | Defl. | Load | Defl. |
| 1-22 | A-1 | 2100 | 33 | 2510 | 44 | 19 | 33 | 2-1 | A-44 | 2340 | 37 | *2530 | *43 | 8 | 16 |
| | 2 | 1820 | 29 | 2280 | 39 | 25 | 34 | | 45 | 1830 | 29 | 2575 | 40 | 40 | 37 |
| | 3 | 2336 | 38 | 2830 | 48 | 21 | 26 | | J-1 | 2355 | 40 | 2480 | 49 | 5 | 22 |
| | 4 | 2175 | 32 | 2510 | 45 | 15 | 40 | 2-2 | A-46 | 2125 | 31 | 2925 | 44 | 37 | 41 |
| | 5 | 2122 | 35 | 2430 | 47 | 14 | 34 | | 47 | 2100 | 34 | 2170 | 36 | 3 | 5 |
| 1-23 | 6 | *1725 | *32 | *2000 | *39 | 15 | 21 | | 48 | 2000 | 31 | 2600 | 44 | 30 | 41 |
| | 7 | 2265 | 35 | 2360 | 41 | 4 | 17 | | 49 | 1980 | 31 | 2100 | 32 | 6 | 3 |
| | 8 | 2000 | 31 | 2640 | 42 | 32 | 34 | | 50 | 1975 | 31 | 2630 | 43 | 33 | 38 |
| | 9 | 2358 | 35 | 2675 | 42 | 13 | 20 | | J-1 | 2100 | 43 | 2470 | 51 | 17 | 18 |
| | 10 | 2114 | 33 | 2215 | 40 | 4 | 21 | 2-3 | A-51 | 2132 | 35 | 2565 | 43 | 20 | 22 |
| 1-25 | 11 | 1930 | 30 | *2130 | *38 | 10 | 26 | | 52 | 2116 | 32 | 2550 | 44 | 20 | 37 |
| | 12 | 2362 | 32 | 2500 | 35 | 5 | 9 | | 53 | 1950 | 30 | 2175 | 34 | 11 | 13 |
| | 13 | | | | | | | | 54 | *1867 | *28 | 2250 | 35 | 20 | 25 |
| | 14 | 2265 | 31 | *2945 | *40 | 30 | 29 | | 55 | 2055 | 34 | 2435 | 50 | 18 | 47 |
| | 15 | 2062 | 36 | 2680 | 39 | 29 | 8 | | J-1 | 2211 | 40 | 2500 | 46 | 13 | 15 |
| 1-26 | 16 | 1968 | 32 | 2145 | 33 | 8 | 3 | 2-4 | A-56 | 1925 | 33 | 2375 | 44 | 23 | 33 |
| | 17 | 2200 | 35 | 2630 | 44 | 19 | 25 | | 57 | 2120 | 37 | 2110 | 36 | **0.4**† | **2** |
| | 18 | 2175 | 35 | 2465 | 39 | 13 | 11 | | 58 | 1850 | 30 | 2320 | 39 | 25 | 30 |
| | 19 | 2106 | 32 | 2400 | 37 | 13 | 15 | | 59 | 2085 | 33 | 2000 | 29 | **4** | **12** |
| | 20 | *1618 | *28 | 2175 | 37 | 34 | 32 | | 60 | *2015 | *34 | 2490 | 44 | 23 | 29 |
| 1-27 | 21 | *1778 | *31 | 2275 | 37 | 27 | 19 | | J-1 | 2130 | 36 | 2525 | 40 | 18 | 11 |
| | 22 | 2175 | 32 | 2525 | 41 | 16 | 23 | 2-5 | A-61 | 2170 | 30 | 2505 | 38 | 15 | 26 |
| | 23 | 2265 | 36 | 2622 | 45 | 15 | 25 | | 62 | 2475 | 39 | 2820 | 49 | 13 | 25 |
| | 24 | 2192 | 31 | 2640 | 39 | 20 | 25 | | 63 | *1632 | *27 | 2320 | 40 | 42 | 48 |
| | 25 | 2180 | 34 | 2425 | 37 | 11 | 8 | | 64 | 2320 | 36 | *1860 | *30 | **19** | **16** |
| 1-28 | 26 | 2080 | 34 | 2360 | 42 | 13 | 23 | | 65 | *1860 | *31 | *1800 | *28 | **3** | **9** |
| | 27 | 1911 | 32 | 2255 | 39 | 18 | 21 | 2-6 | 66 | 1975 | 32 | *1895 | *32 | **5** | **0** |
| | 28 | 2205 | 36 | 2345 | 38 | 6 | 5 | | 67 | 2060 | 35 | 2765 | 36 | 14 | 2 |
| | 29 | 2197 | 35 | *2400 | *36 | 9 | 2 | | 68 | 1810 | 28 | 2520 | 41 | 39 | 46 |
| | 30 | *2185 | *35 | 2550 | 45 | 16 | 28 | | 69 | 2000 | 32 | 2425 | 38 | 21 | 18 |
| 1-29 | 31 | *1821 | *31 | 2130 | 37 | 16 | 19 | | 70 | 2000 | 35 | *1650 | *28 | **17** | **20** |
| | 32 | *1845 | *31 | *1990 | *32 | 7 | 3 | | J A | 2000 | 32 | 2640 | 42 | 32 | 31 |
| | 33 | *2135 | *28 | 2500 | 38 | 17 | 35 | 2-8 | A-71 | 1960 | 33 | 2235 | 41 | 14 | 24 |
| | 34 | *1900 | *30 | 2000 | 31 | 5 | 3 | | 72 | 2325 | 36 | *2290 | *38 | **1** | 5 |
| | 35 | 1970 | 30 | 2110 | 34 | 7 | 13 | | 73 | 2000 | 31 | 2595 | 44 | 29 | 41 |
| | J-2 | | | | | | | | 74 | 1935 | 30 | 2475 | 38 | 27 | 26 |
| 1-30 | A-36 | 1868 | 29 | 2210 | 40 | 18 | 37 | | 75 | 1925 | 32 | 2592 | 45 | 34 | 40 |
| | 37 | 1832 | 29 | 2310 | 37 | 26 | 27 | | J A | 2215 | 38 | 2120 | 44 | **4** | 15 |
| | 38 | 2000 | 29 | 2150 | 35 | 7 | 20 | 2-9 | A-77 | 2150 | 31 | 2490 | 43 | 15 | 38 |
| | 39 | 1955 | 30 | 1875 | 30 | **4** | 0 | | 78 | 2020 | 31 | 2515 | 43 | 24 | 38 |
| | 40 | 1940 | 29 | *1970 | *32 | 1 | 10 | | 79 | 2095 | 31 | 2235 | 35 | 6 | 12 |
| | J-1 | 2236 | 41 | 2600 | 48 | 16 | 17 | | N-80 | 2000 | 31 | 1920 | 33 | **4** | 6 |
| 2-1 | A-41 | 2175 | 33 | 2310 | 40 | 6 | 21 | | N-81 | 1920 | 27 | 2340 | 40 | 21 | 48 |
| | 42 | 1773 | 29 | 2360 | 45 | 33 | 55 | | S-82 | 2100 | 31 | 2305 | 34 | 9 | - |
| | 43 | 2233 | 37 | 2500 | 46 | 11 | 24 | | S-83 | 1940 | 35 | 2135 | 43 | 10 | 22 |

* Defective

†A Decrease is shown by bold-face figures

before the American Institute of Mining Engineers, on February 20, 1896. This aroused a widespread interest and discussion among users of cast iron, and, so far as the sub-committee has been able to determine, it has not been shown that any one, either in this country or abroad, has antedated Mr. Outerbridge in his work in this line.

The Franklin Institute therefore recommends the award to him of the John Scott Legacy Premium and Medal.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, June 2, 1897.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,
*Chairman Committee on Science and the Arts.*

[Award confirmed by the Directors of City Trusts.]

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## THE WILLIAMS TYPEWRITING MACHINE.

[*Being the report of the Franklin Institute, acting through its Committee on Science and the Arts, on the invention of John N. Williams.*]

[No. 1956.] HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 22, 1897.

The Franklin Institute of the State of Pennsylvania, for the Promotion of the Mechanic Arts, acting through its Committee on Science and the Arts, investigating the merits of the Williams Typewriting Machine, reports as follows:

This is a keyboard, type-bar, machine, with the type-bars divided into two groups, before and behind the platen, at the top of the machine (*Fig. 1*); the types striking the platen and printing on top. The movement of the type-bar is similar to that of the upper limb of a parallel ruler (*Fig. 2*) set on edge and carrying a type on the end of the upper limb, resting on an inked pad when in position as if the two limbs were together, and striking the platen when extended. Each type-bar (of which there are twenty-eight) carries

three letters or characters, as may be, and the platen has two shifts, bringing all of them (eighty-four) into action. The paper passes down on both sides of the platen and is rolled in cradles provided for it on both sides.

The printing is in full view of the operator, and being done directly from the type, has a sharpness not attainable with a ribbon.

The applicants claim for it the following points of superiority, which are discussed in their order.

(1) *Visible Writing.*—There are some other machines which write visibly; but there is no other which writes visibly direct from the type, giving, at the same time, the quality of work and the convenience of inspection.

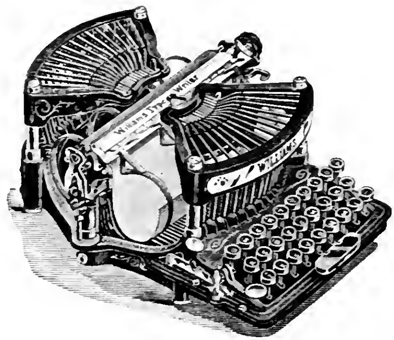


FIG. 1.

(2) *Direct Inking.*—There is one other keyboard machine, and some single-hand machines, which ink direct from the type. The ink-pad is more easily and quickly re-inked or changed, for change of color, than on any other machine.

(3) *Speed.*—The machine has high speed, probably beyond that of any operator; but with most of the first-class machines the limit of speed is that of the operator, and not of the machine.

(4) *Alignment.*—The alignment is necessarily perfect, because the bearing is guided; but this feature is in some other machines.

(5) *Manifolding.*—The Williams Machine is an excellent manifolder. It has a certain liability, in heavy manifolding,

to take an impression from the edge of the upper-case letter, on the top sheet, which, however, by special care on the part of the operator, can be avoided.

(6) *Mimeographing.*—It cannot fail to make first-class stencils for mimeographic work.

(7) *Keyboard.*—The keyboard has the advantage and facilities of compactness and convenience over the keyboard on some other machines, having two shifts.

(8) *Carriage.*—The carriage is light-running and convenient.

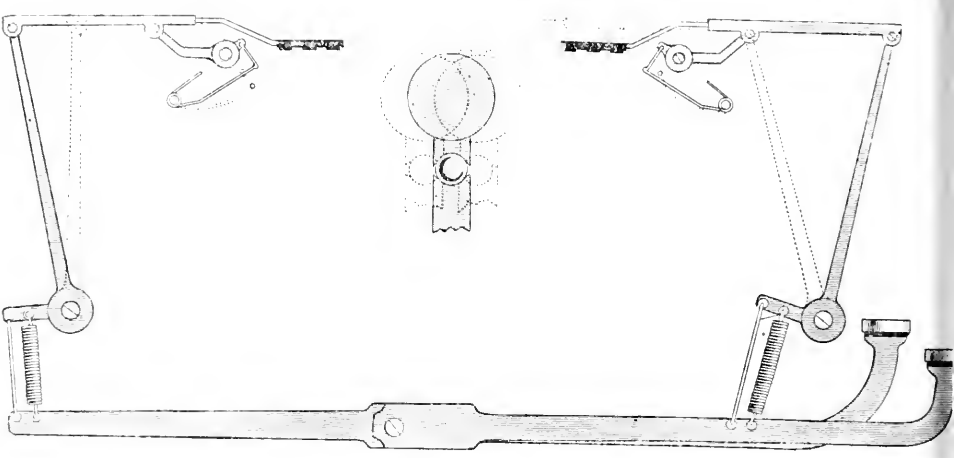


FIG. 2.

(9) *Carriage Lock.*—This is a device by which it can readily be fastened in place, for shipment.

(10) *Line Lock.*—This device locks the machine at the end of the line, and prevents the stroke of the type, with a further capability of two letters, disengagement for which is done by a touch on the key, enabling the use of these two letters where they are needed for completion of a word, which is a very convient feature.

(11) *Line Spacing.*—This machine has three adjustments for spacing, while most machines have two; but there are

several other machines by which a similar wide range of adjustment can be made, quite as conveniently as on this.

(12) *Marginal Stop.*—This is not dissimilar to that of other machines.

(13) *Interchangeable Platens.* — Platens on several of the machines are interchangeable.

(14) *Economy of Maintenance.* — There is considerable economy as compared with machines using ribbons, which is paralleled by the other machines using pads.

(15) *Type always Clean.*—This is correctly stated.

(16) *Tabulating.*—This machine can be used very advantageously for tabular work, due to the fact that the work is in plain view, and the platen can be put in any position required, regardless of its feed.

(17) *Quality of Work.*—There is no doubt that the work from a machine printing directly from the type is superior to that which prints through a ribbon; but this advantage is shared by other machines which print directly from the type.

(18) *Simplicity, Compactness and Durability.*—This machine is simple and compact, and all parts are in plain view and easily accessible. There appears to be no reason why it should not be quite satisfactorily durable.

The Williams' Machine has a light, free touch and positive movement of its platen escapement.

This machine is covered by, and described in, the following patents to John N. Williams, to wit: No. 523,028, dated July 17, 1894; No. 501,753, dated July 18, 1893; No. 442,697, dated December 16, 1890; and also a patent to James Brady, No. 431,869, dated July 8, 1890, which covers the escapement only; and, while this is a very material part of the machine, it is so simple that it is not necessary to take account of it in considering the general merits of the machine.

In view of these advantages, the Franklin Institute recommends the award of the John Scott Legacy Premium and Medal to John N. Williams for his improvements in typewriting machines.

Adopted at the stated meeting of the Committee on Science and the Arts, held Wednesday, June 2, 1897.

JOHN BIRKINBINE, *President.*
WM. H. WAHL, *Secretary.*

Countersigned by

JAMES CHRISTIE,

*Chairman of the*
*Committee on Science and the Arts.*

[Award confirmed by the Board of Directors of City Trusts.]

## BOOK NOTICE.

*The Metallographist.* A quarterly publication devoted to the study of metals, with special reference to their physics and microstructure, their industrial treatments and applications. Edited by Albert Sauveur. Published by the Boston Testing Laboratories, 446 Tremont Street, Boston, Mass., U. S. A. [Price, $2 per annum.]

The great extension of our accurate knowledge of the metals and alloys employed in the constructive and mechanical arts, that has resulted from the application of refined methods of physical investigation, has made it clear that many of the qualities upon which depend the value of those materials in the arts are determined very largely by the physical conditions attending their production and subsequent manipulation; and that without the full, knowledge of these physical data, chemical composition is apt to prove a most uncertain alliance. It is only necessary, in proof of this statement, to refer to a single fact, namely, the preponderating influence of the heat treatment of the metals upon their structure, the segregation of accessory constituentst etc., as revealed by the examination under the microscope; and many other confirmatory facts could be adduced.

The new magazine has an important and constantly widening field to call its own.

The editor is well and favorably known as an industrious and intelligent investigator of the micro-structure of metals, and, if the contents of the first two numbers be taken as a specimen of those to follow, it gives promise of proving a substantial acquisition to current engineering literature. W.

# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, June 15, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, June 15, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 46 members and 2 visitors.

Additions to membership since last report, 9.

The Secretary reported the resignation of Prof. F. L. Garrison from the Committee on Science and the Arts. The vacancy was filled by the election of Mr. A. M. Greene, Jr.

Mr. Wilfred Lewis read a paper describing "An Inertia Indicator," which was illustrated with a specimen of the apparatus and blackboard explanations. This ingenious mechanical device was originally designed by the inventor for the purpose of determining the reaction of travelling cranes on their tramways, and is susceptible of application in many other situations. Referred to the Committee on Science and the Arts for investigation and report.

Mr. Edwin L. Decker, of Carlstadt, N. J., described and illustrated by means of a series of lantern slides the "Gas Composimeter," devised by Messrs. Uehling, Steinbart & Co., of Newark, N. J., for the automatic analysis of the flue gases discharged from steam boiler furnaces. The instrument makes a continuous record of the percentage of carbon dioxide in furnace flues, and is intended to be used as an indicator in boiler-rooms to serve as a controller in the economic service of boiler fires.

The Secretary presented his monthly report, which included an exhibition of a series of views of Philippine Islands, loaned for the purpose by Dr. Brooks, Superintendent of the Public Schools.

Adjourned. WM. H. WAHL, *Secretary.*

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the special meeting held Wednesday, June 22, 1898.*]

PROF. L. F. RONDINELLA in the Chair.

The following reports were adopted:

*Severy Impression Process.*—Melvin L. Severy, Boston, Mass.

ABSTRACT.—The purpose of this invention is to do away with the necessity of specially preparing the impression bed of a printing press to properly receive the impression of the form to be printed—in other words, to do away with the process known in the trade as the "make-ready."

To accomplish this result, the inventor makes use of an elastic wire fabric as the tympan or covering of the impression bed of the press, in place of the covering commonly in use. This fabric is formed of steel wire, and its surface presents a close array of these wires, resembling what is known in the textile arts as "card clothing." In printing, this fabric is covered with a thin sheet of hard rubber. The tympan thus formed seems to combine, in marked degree, the facility of a soft tympan with the qualities of a hard one.

A series of tests of the Severy tympan, made by the Committee on a quarto platen press, indicated that the Severy tympan afforded decided advantage over the ordinary impression tympan, rendering from a number of various forms, without special "make-ready," such excellent impressions as give full promise of valuable economic results.

The report concludes as follows: In conclusion, while the investigating committee feels constrained to withhold its unqualified acceptance of the very broad claims to usefulness made in behalf of this invention, pending the ascertainment of the results of its practical application in continuous use, it is, nevertheless, of the opinion that Severy Impression Process deserves recognition at the hands of the Institute as an invention both original and important. The award of the Scott Premium and Medal is recommended. The Severy Impression Process is protected by U. S. Letters-Patent No. 549.641, November 12, 1895. [*Sub-Committee.*—Louis E. Levy, Chairman; Hugo Bilgram, Wilfred Lewis, Edward Stern, George H. Buchanan, Frank E. Manning, Wm. H. Greene, Samuel Sartain.]

*Improvements in Roentgen Ray Tubes.*—H. Lyman Sayen, Philadelphia.

ABSTRACT.—The object of this invention is to increase the life, range of usefulness and efficiency of X-Ray tubes by providing them with automatic means of obtaining and maintaining the desired vacuum for the work to be done. It is protected by U. S. Letters Patent No. 594,036, November 23, 1897.

The invention under consideration, and as described in the letters-patent above referred to, aims at the provision of special means for the automatic control of high vacuum tubes of any description. The means provided consist of a shunt circuit of adjustable resistance, so adapted to the tube that variations in the degree of vacuum in the main tube will produce corresponding variations in the currents in the shunt circuit. These currents react in such a way as to control the vacuum in the main tube. The Sayen tube will be found fully described and illustrated in the *Journal* for June, 1898, and reference is made to this article for further details. The Scott award is recommended to the inventor. [*Sub-Committee.*—Arthur W. Goodspeed, Chairman; D. Anson Partridge, C. W. Reed.]

*Self-Lubricating Journal Box.*—Jos. S. Cook, Atlanta, Ga.

This improvement consists in surrounding the bearing part of the box with a cavity in which the grease is placed, the journal-bearing being connected with this cavity by holes in the top and bottom, and also by a slot formed by removing some of the metal at the inner part of the joint of the two parts of the box. The cup has a plug which closes the cavity, but which is removed when filling. The lubricant is introduced in any convenient manner.

In use the cavity is filled with grease, which completely surrounds the

metal of the bearing part of the box, the journal producing sufficient heat to melt the grease, and permitting it to flow through the holes and the slot.

The slightly-increased cost of this box in weight of metal and in covering the casting producing the cavity is offset by the removal of grease-cups and candle-oilers often used with ordinary boxes, and the making of a journal-box compact and covered, preventing dust and other foreign matter from getting into the journal, and having a cavity below the journal, allowing grit and other particles to settle.

The report concludes that this journal-box is an improvement over others of its class, being more compact and closed, yet well adapted to the use of Albany grease or similar lubricating substances which depend upon a rise in temperature to lubricate.

The Certificate of Merit is granted to the inventor. [*Sub-Committee.*—J. Logan Fitts, Chairman; H. F. Colvin, C. A. Hexamer, Hugo Bilgram.]

*Steam-Trap.*—Antoine Heintz, Liège, Belgium.

ABSTRACT.—The Heintz steam-trap consists of a metallic box in the shape of a semicircle, with a lid held on by bolts, the joint rendered tight by a gasket, and containing the following parts:

At one side of this box is a flange for attaching a discharge from a steam system, and at the other side provision is made for an attachment for carrying off the discharge from the trap. A spring is provided at one end of the tube, for keeping it tight against a screw which regulates the amount of, and temperature at, the opening of the valve.

The operation is as follows: Supposing the trap to be cold and the valve open, water may pass through, but when steam comes to the trap the tube becomes heated. This tube, being elliptical in section and filled with a volatile hydrocarbon, elongates as the heat vaporizes the hydrocarbon, thus producing pressure. After the tube loses its heat, the valve opens again, allowing more liquid to pass, but closes as soon as there is enough heat given to the tube to expand it. Experiments made by the investigating committee demonstrated that the trap operated well under high and low pressures.

The sub-committee's investigation disclosed the fact that the Heintz trap is an improved form of trap devised originally by Mr. Alfred Peyer, and constructed by Schmerber Brothers, of Mulhouse, Alsace. The scheme of the bent tube with its contained liquid is exactly similar to the Heintz tube, and its operation is also practically identical.

The report finds that the Heintz trap is a successful improvement of the application of the bent tube originally made for this purpose by Mr. Peyer. The applicant is awarded a Certificate of Merit. [*Sub-Committee.*—Arthur M. Green, Jr., Chairman; J. M. Emanuel, Frank P. Brown, Robt. D. Kinney, Henry F. Colvin.]

*Roller-Bearing.*—John W. Hyatt, Newark, N. J.

ABSTRACT.—This roller-bearing resembles a closely-wound spiral spring, made from a strip of steel of a rectangular section, forming an elastic spirally-wound tubular roller. The mode of supporting the rollers and the frames confining them are substantially identical with the methods long in use with solid rollers.

The investigating committee made comparative experiments to ascertain the relative resistance of the Hyatt roller-bearing and a solid steel roller to endwise thrust when confined between plates to which pressure was applied. The resistance to rolling was accurately measured by its reaction on the platform of a scale. In one set of experiments the faces of the plates were planed, in another series these faces were left rough as they came from the rolls. The pressures were increased gradually during the tests until a maximum of 25,200 pounds was reached, corresponding to from 700 to 878 pounds per lineal inch of roller.

To make sure that the rigidity arising from the application of screw-pressure might not have given a more favorable result in the case of the flexible roller, a controlling experiment was made, in which the pressure was applied by a weight acting on a lever, in which the pressure would be due to gravity alone.

The results of both sets of experiments were substantially uniform and were distinctly favorable to the Hyatt bearing.

The report is favorable, and recommends the Scott award. [*Sub-Committee.*—James Christie, Chairman; Spencer Fullerton.]

*Compound Locomotive Engine.*—Clifton Reeves, Trenton, N. J.

On reconsideration of this subject, in consideration of a protest from the inventor, the committee confirmed the conclusions of its previous report. See this *Journal*, **145**, 239.

*Counterbalancing Locomotive Driving Wheels.*—Philip Z. Davis, Lometa, Texas.

Action similar to the foregoing was taken in this case (see *Journal*, **144**, 470.)

*Venturi Meter.*—Clemens Herschell, Boston, Mass.

This is an application of the well-known principle of the Venturi tube to the measurement of the flow of water in quantities so large as to be incapable of measurement by any of the meters in common use. There was also submitted, in connection with the Venturi meter, a registering device invented by Messrs. Fredk. N. Connet and Walter W. Jackson, of Providence, R. I.

The inventions supplemented each other, and were reported on conjointly. The committee directed the report to be referred for publication *in extenso.*

The Elliott-Cresson Medal is proposed in acknowledgment of the invention of Mr. Herschell, and the Scott award is recommended to Messrs. Connet and Jackson. [*Sub-Committee.*—John C. Trautwine, Jr., Chairman; John E. Codman, Rudolph Hering.]

*Smoke Nuisance Ordinance.*—The sub-committee charged with the preparation of a draft of an ordinance to be transmitted, with the approval of the Institute, to the Bureau of Health of the city of Philadelphia, presented such a draft, which was very freely discussed, and in consequence of several criticisms upon certain of its features, it was referred back to the sub-committee for amendment.

Mr. A. M. Greene, Jr., a newly-elected member of the Committee, was presented to the chair, and took his seat as a member. W.

# JOURNAL

OF THE

# FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVI, No. 2. 73D YEAR. AUGUST, 1898



## THE FRANKLIN INSTITUTE.

*Stated Meeting, April 20, 1898.*

## RECENT PROGRESS IN THE DEVELOPMENT OF PNEUMATIC DISPATCH TUBES.

BY B. C. BATCHELLER.

As you all know, pneumatic dispatch tubes are not an invention of recent date; that is to say, their commercial application began forty-five years ago. Every one is more or less familiar with them, as they are used in large retail stores for the transmission of cash from the various counters to the cashier's desk. Many large office buildings are equipped with them for dispatching messages from one office to another. The Western Union Telegraph Company has used them since 1876 in New York City, to transmit their telegrams from one office to another, it being found more expeditious than the telegraph.

The United States usually takes the lead in the application of mechanical devices, but in the uses of pneumatic dispatch tubes we are behind our European neighbors.

London, Paris, Berlin and Vienna for years have had their pneumatic tube systems for transmitting telegrams between the central and branch post-offices. The service is not confined to the large cities, for Liverpool, Brussels and other smaller cities are now equipped with this modern method of transportation.

There is much misconception of the size, capacity, length and use of the tube systems of Europe, for which the daily press is principally responsible. I have seen it stated that Paris and Berlin are connected by pneumatic tubes. It goes without saying that such a statement is untrue. Many people believe that mail is sent through the tubes, but that is also untrue, for the tubes are not large enough for that purpose. They are used only for the transmission of telegrams and messages. The largest tubes in London are only 3 inches in diameter, while those of Paris and Berlin are about $2\frac{1}{4}$ inches. *Fig. 7* shows the Berlin and London carriers,

The first tube was laid in London in 1853 by the Electric International Telegraph Company, under the direction of Mr. Josiah Latimer Clark. It was $1\frac{1}{2}$ inches in diameter, and extended from Founder's Court to the Stock Exchange, a distance of 220 yards. Year by year the system has been extended, until now the entire business section of the city is covered by a network of tubes radiating from the General Postoffice and terminating in the numerous sub-post-offices. (In England the telegraph is controlled by the Government, and the telegraph offices are in the post-offices.) The tubes are of lead, encased in cast iron and laid in pairs for dispatching in opposite directions. Berlin has a similar system to that of London, but in Paris the tubes are laid in circuits with several stations on a circuit. The carriers are forwarded in trains from one station to another around the circuit.

It is not the purpose of this paper to describe these European systems in detail, but I refer to them to give some idea of the state of the art up to 1893.

Admitting that the European cities have gotten the start of us in point of time, we are bound not to be beaten

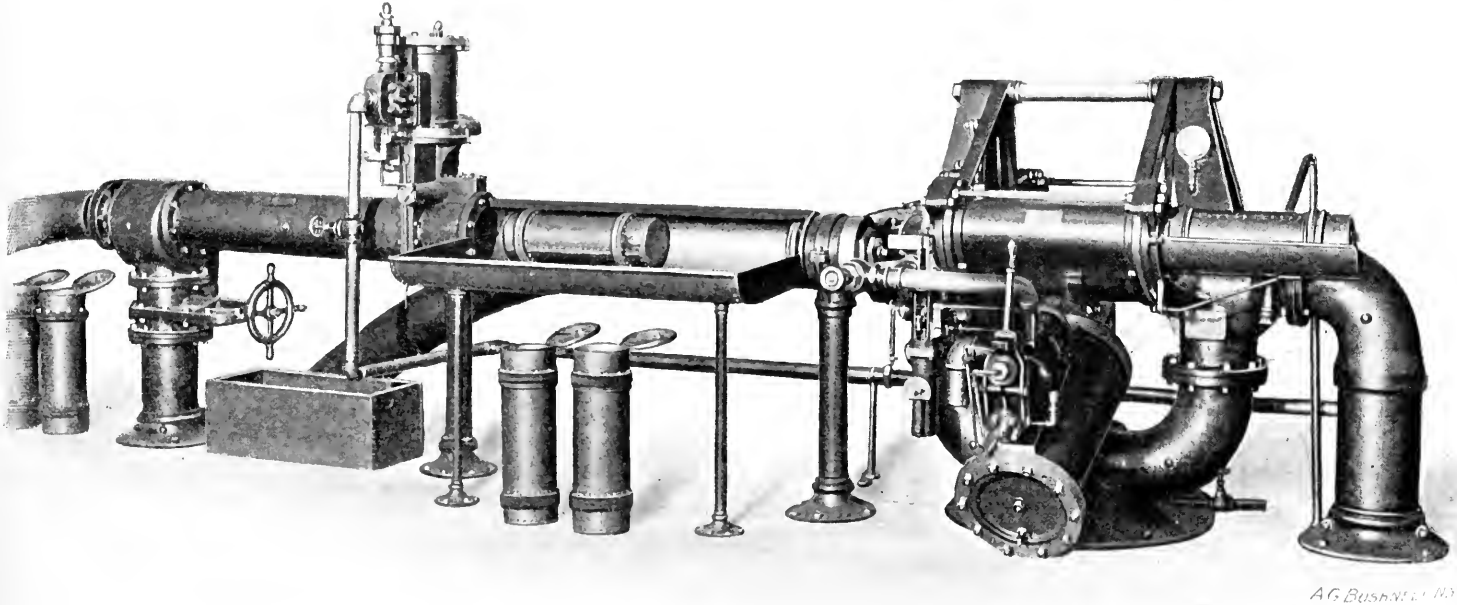



FIG. 1.—Sending apparatus and open receiver, Produce Exchange Line, Main Post-office, New York City.

in the end. While they continue to operate their small 2- and 3-inch tubes for telegrams only, we begin by building 6-inch, and use them to transport mail in large quantities, and the beginning was made in our own city of Philadelphia five years ago, when the first line was opened by the Hon. John Wanamaker, then Postmaster-General.

It may seem to many of you like a simple step, from 3-inch to 6-inch tubes, but I will say from experience that the small tubes were no guide or help to us in building larger ones. The methods of operation and apparatus used with the small tubes could not be applied to the larger. The principal reason for this lies in the greatly increased weight of the cartridge, or, as we term it, carrier, that is dispatched through the tube. The weight causes friction against the walls of the tube and is a storehouse for energy that must be taken care of when the carrier is brought to rest. A heavy carrier is like a heavy train on a railway. The carriers used in the small tubes are stopped by allowing them to strike some solid object, which can be done without injury to them, but the large carriers used in 6-and 8-inch tubes must be brought to rest gradually by means of an air cushion, and this involves the use of automatic receiving apparatus not required in the small tubes. The more important problems that had to be solved in designing the system of 6-inch tubes were the sending apparatus, the receiving apparatus, the carrier and the tubes. This was for a line of two stations. When intermediate stations are used the problems of switches and automatic receiving apparatus to select carriers at their destined stations had to be met.

The first double line of tubes built in Philadelphia was laid from the main Post-office, Ninth and Chestnut Streets, along Chestnut Street to the sub-post-office, now located in the Bourse, a distance of about 3,000 feet. The tubes were made of cast-iron water pipe, bored upon the interior to an exact diameter of $6\frac{1}{8}$ inches. The lengths were joined together by making a counter bore at the bottom of the bells, into which the machined end of the adjoining length fitted, and filling the bell with yarn and lead caulked in the usual manner.

Where it became necessary to turn corners seamless brass tubing was used, bent to a radius of not less than 6 feet. The tubes were simply buried in the ground, one above the other, at a depth varying from 3 to 10 feet, depending upon the location of other underground construction, such as water and gas pipes, conduits, sewers, etc.

The line was, and still is, operated by an air compressor located in the basement of the main Post-office. This compressor is of the duplex type, built by the Clayton Air Compressor Works, and does not differ, except in relative size of cylinders, from the compressors on the market for general purposes. It develops about 25 horse-power and compresses about 800 cubic feet of free air per minute to a pressure of 7 pounds per square inch. The dispatching and receiving apparatus is located on the main floor of the Post-office near the cancelling machines and in the rear room of the sub-post-office in the basement of the Bourse.

The tubes are in operation from nine o'clock in the morning until seven in the evening, excepting the noon hour.

The air current flows continuously from the main Post-office to the Bourse through one tube and returns to the main Post-office through the other, thus forming a loop with the return end connected to the suction pipe of the compressor at the Post-office. There is an opening in the tube to the atmosphere near where it is connected to the compressor, so that the entire circuit contains air at a pressure above the atmosphere.

It is a pressure system rather than a vacuum system as these terms are commonly understood.

Carriers occupy sixty seconds in transit from the Post-office to the Bourse and fifty-five seconds for the return trip. They can be dispatched at six-second intervals or ten per minute in each direction.

This 6-inch tube has been in operation for five years and is doing good service to-day.

Not content with this, the promotors of this enterprise decided to go one step further and build an 8-inch tube.

The second line was laid in New York City between the main Post-office and branch Post-office P, in the Produce

Exchange Building. It is similar in method of operation to the first Philadelphia line, but somewhat longer, the distance between stations being about 4,000 feet. Some improvements were made in the sending apparatus, utilizing the air

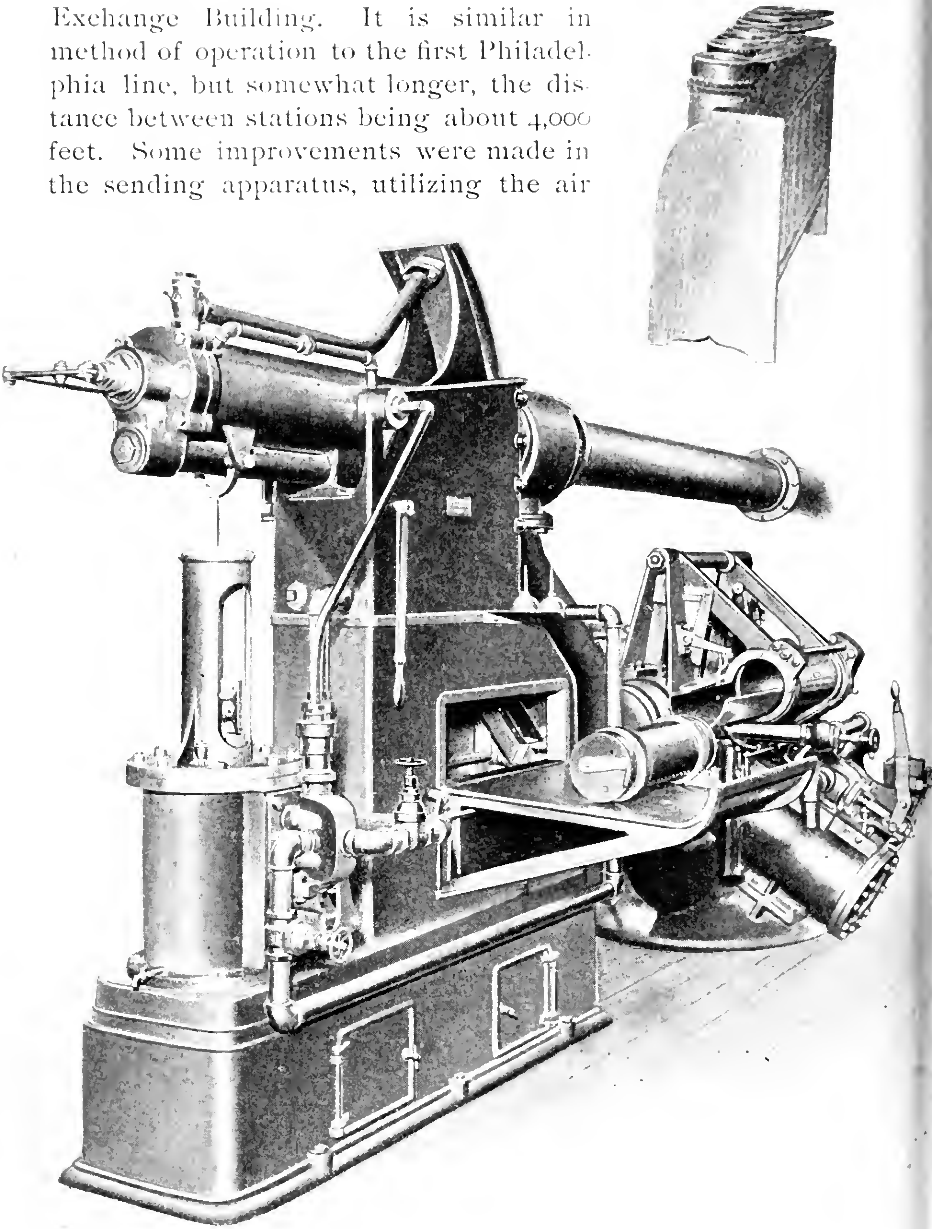


FIG 2.—Sending apparatus and closed receiver, Produce Exchange Line, Postal Station H, New York City.

pressure to do what was formerly done by manual labor. See *Figs. 1* and *2*,

When this Produce Exchange circuit was opened for business the construction of a second circuit was well under way in New York, extending from the main Post-office to branch Post-office H, on Forty-fourth Street near the Grand Central Depot, a distance of $3\frac{1}{2}$ miles, with three intermediate stations on the line: at Postal Station D, Third Avenue and Eighth Street; Madison Square Postal Station and Postal Station F, at Third Avenue and Twenty-eighth Street.

The main line of this circuit was opened February 11th, but the receiving apparatus for the intermediate stations is not yet completed. This is the longest circuit built thus far. The inside diameter of the tubes, like the Produce Exchange circuit, is $8\frac{1}{8}$ inches. There are two tubes, one for dispatching up-town and the other down-town. They are operated by air compressors, located one at the Post-office and the other at Forty-fourth Street. The time of transit of the carriers in either direction is about seven minutes. The air pressure at the compressors is 13 pounds.

During the autumn of last year a circuit of 8-inch tubes was constructed in Boston between the main Post-office and the North Union Railway Station, a distance of about 4,500 feet, or a little less than 1 mile. This is similar in all respects to the Produce Exchange line in New York. It is used to transport the outgoing mail from the post-office to the trains, and the incoming mail from the trains to the Post-office.

On Thursday, April 7th, a circuit of tubes between the main Post-office and the Pennsylvania Railroad Station at Broad Street, in this city, was formally opened for the transportation of mail to and from the trains. A little later there is to be an intermediate station established at the Reading Terminal. The tubes are laid from the Post-office through Chant Street to Tenth Street, up Tenth Street to Filbert Street, and out Filbert Street to the Pennsylvania Station.

Another circuit is partially constructed between the main Post-office in New York and the main Post-office in Brooklyn, by way of the Brooklyn Bridge.

The total length of 8-inch tubing in all these circuits is a little more than 17 miles. This has all been manufactured and laid under ground, with the exception of the incompleted part of the Brooklyn Bridge line, since August 1st, last year.

THEORY.

A current of air may be made to flow through a tube by either pumping the air in at one end under a pressure above that of the atmosphere, or by exhausting the air, thereby reducing its pressure below that of the atmosphere. In either case it is the difference of pressure at the two ends of the tube that causes the air to flow. Both methods are used in operating the London and Paris tubes, and both are used in the cash systems of our large retail stores, but all of our large tubes are operated by compressing the air so that the air-pressure in the tubes is at all points above that of the atmosphere. The determining of which system shall be adopted depends largely upon circumstances.

In the operation of short lines of small tubes, all of the machinery and apparatus can be concentrated at one point by using compressed air in the outgoing tubes and rarified air in the incoming tubes.

So far as power is concerned, the exhaust method is more economical, because nearly all the power is consumed in overcoming the friction of the air in the tube, and this friction varies directly with the density of the air.

There are several reasons why the compressed-air method of operation is better: first, if there are any leaks in the tubes, and they happen to be laid in the wet ground, water will be drawn into the tubes when the air is exhausted, while it will be kept out if the air-pressure is above the atmospheric; second, air-cushions, for checking the speed of the carriers when they arrive at a station, are much more efficient and effective with compressed than rarified air; third, cylinders and pistons used to operate sending and receiving apparatus can be made smaller when compressed air is used.

There are two methods of using the current of compressed or rarefied air in the operation of a line, and these

are termed the intermittent and constant methods. The first consists in storing compressed air in a suitable tank, or by exhausting the air from a tank; then when we wish to dispatch a carrier we place it in the tube and connect the tube with the tank by opening a valve. As soon as the carrier arrives at the distant end of the tube the valve is closed, and the air soon ceases to flow. When a long interval of time elapses between the dispatching of carriers, this is the most economical method of operation; but if carriers have to be dispatched frequently, a great deal of time would be lost in starting and stopping the air current throughout the whole length of the tube. Under these conditions the second method, which consists in maintaining a constant current of air in the tube, and in having the carriers inserted and ejected at the ends of the tube without stopping the current of air for any appreciable length of time, is much more rapid and efficient. This latter method is the one used in the operation of all our large tubes. The current of air flows continuously all day, and the carriers containing mail are swept along like boats in a rapidly-flowing stream. The analogy is quite perfect. The boats obstruct the flow of water and check its speed but little. In order to compute the speed with which the boats will pass from one point to another, we have only to know the speed of the stream between those points when no boat is in it. The presence of the boats does not change the speed appreciably. So it is with carriers in a pneumatic tube; the air flows nearly as rapidly when a carrier is in a tube as when there is none. The friction of the carrier against the inner surface of the tube creates a slight drag, but it checks the speed of the air only a little. Therefore, in order to know the speed with which a carrier will be transported from one station to another, we need only to know the velocity with which the air flows through the tube when no carrier is present.

Let us assume a simple case of an 8-inch tube 1 mile long, connected at one end to a tank in which a constant air pressure of 10 pounds per square inch is maintained, the other end of the tube being opened to the atmosphere.

I have constructed a diagram showing the air pressure at all points along the tube (see *Fig. 3*). The abscissæ represents lengths of tube in feet and the ordinates air pressure

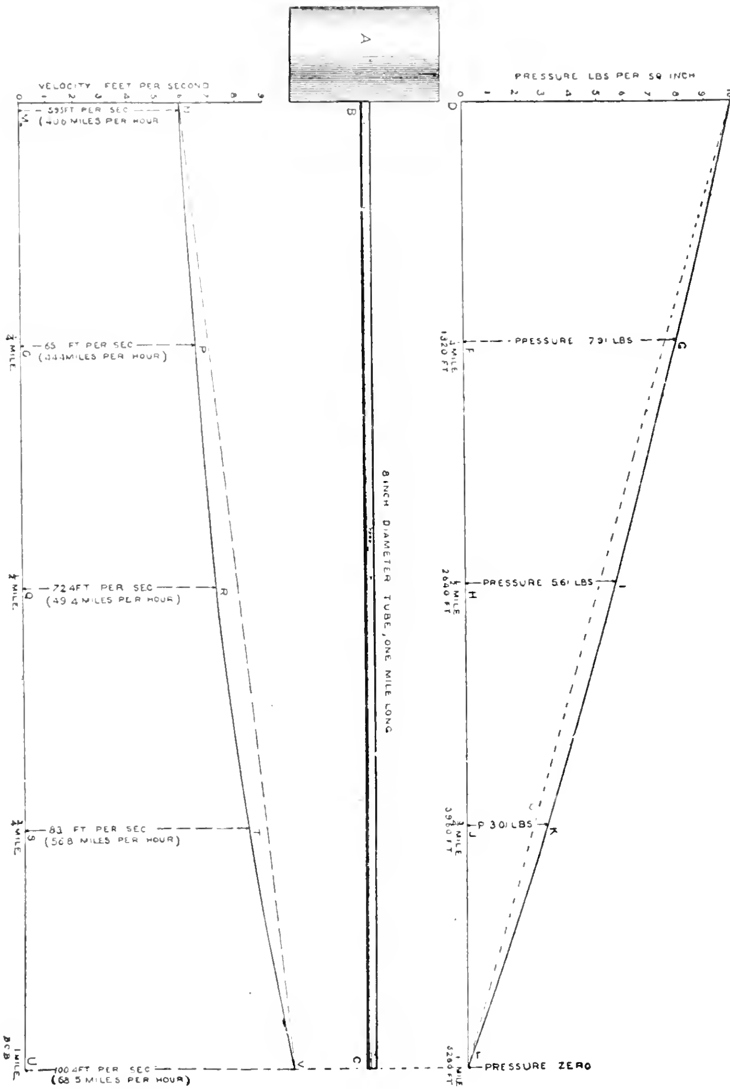



FIG. 3.—Diagram showing the pressure and velocity of the air in a pneumatic tube.

above the atmospheric in pounds per square inch. At the tank end the pressure is 10 pounds, at the open end zero, and at the quarter, half and three-quarter mile points 7·91, 5·61 and

3·01 pounds respectively. It will be observed that the pressure curve is slightly convex upwards. This is due to the expansion of the air in the tube. The pressure curve of the flow of water in a pipe is a straight line. The fall of pressure along the tube is analagous to the fall of level in a flowing stream or to the fall of potential along a wire in which a current of electricity is flowing.

I have constructed another diagram showing the velocity of the air at every point along the tube. The abscissæ are lengths of tube in feet, the ordinates velocity of the air in feet per second. The velocity at the tank end, quarter, half and three-quarter mile points and at the opened end is 59·5, 65, 72, 83 and 100·4 feet per second, respectively. It will be noticed that the velocity of the air increases as it flows along the tube, and that it increases more rapidly as it approaches the open end of the tube. The increase of velocity is due to the expansion of the air as it flows along the tube, and the expansion results from the fall of pressure. The mean of all the ordinates gives us the mean velocity, which enables us to compute the time of transit of a carrier through the tube. We can also determine from this velocity curve the time of transit between any two points on the tube which may represent stations.

From the velocity with which the air is discharged from the open end of the tube we compute the quantity of air that must be compressed per minute. The quantity of free air and the initial pressure enables us to compute the horsepower required to maintain the current of air constantly flowing. Of course, there are numerous factors which enter into these computations which are only determined by experiment and experience, such, for example, as the quantity of air that escapes from the tube at the sending and receiving apparatus; the fall of pressure of the air in flowing around bends and through the apparatus; the efficiency of the air compressor, etc.

The temperature of the air, from the instant it enters the compressor until it is discharged at the open end of the tube, is an interesting and important factor in the theory of pneumatic transmission. Since pressures above 25

pounds per square inch are seldom used, the air cylinders of the compressors are not water-jacketed, hence the air is heated by compression to a temperature found by measurement to be above the theoretical amount that we should expect from thermodynamic formulæ. The reason for this will be understood when we remember that the incoming air is heated by contact with the hot walls of the cylinder. When air is compressed to 7 pounds per square inch, it leaves the compressing cylinder at about 160° F. We should expect much of this heat to be soon lost by conduction and radiation through the walls of the tube, and as the air flows through the tube, constantly expanding, it would not be unreasonable to expect considerable reduction in temperature by the time it reached the open end of the tube—a temperature considerably below that of the atmosphere. Experience teaches us that after leaving the compressor the temperature of the air falls rapidly, and that the temperature in the tubes underground is almost constant, being about that of the surrounding earth. The compression may be considered as adiabatic and the expansion as isothermal with very little error.

The atmosphere at all times contains more or less moisture in a state of vapor, and its capacity for water vapor varies directly with its temperature; that is to say, the higher the temperature the more water vapor will the air contain, and *vice versa.* The temperature of the air in the tubes is frequently and usually lower than the atmosphere out-of-doors, consequently it often happens that moisture is deposited upon the interior of the tubes. The quantity is never very great, but sometimes the carriers come out of the tube coated upon the exterior with a thin film of moisture. We use the same air over and over, thereby avoiding drawing into the tube large quantities of moisture-laden air.

Having thus briefly discussed the theory of the flow of air in long tubes, we will now consider some of the necessary mechanical details. Keeping in mind our 8-inch tube, 1 mile long, connected to a tank of compressed air at one end and open to the atmosphere at the other, thereby main-

taining a constant flow of air through the tube. In order to utilize this tube and air current for the transportation of mail or merchandise, we must have some means of inserting carriers containing the material to be transported into the tube, without the escape of air. In other words, we must have some form of sending apparatus or transmitter. This might be accomplished by having a section of the tube

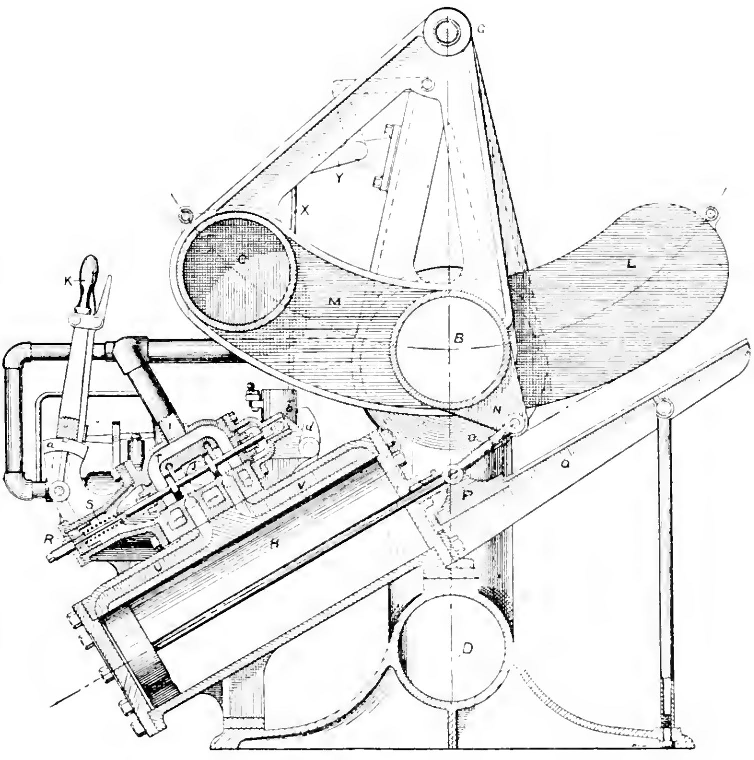



FIG. 4.—Cross-section of sending apparatus.

with valves at each end to stop the flow through this section and conduct it through a by-pass. A carrier could then be inserted into this section of tube and the valves be turned to their normal position. Or, what we find to be more practical is to have a section of the tube that can be swung out of line with the main tube to receive a carrier

and then swung back into line again. This is the form of sending apparatus that we use in all our 8-inch tubes. The section of tube is swung by a cylinder and piston operated by the air pressure taken from the tube (see *Figs. 1* and *4*.) The attendant has only to place a carrier in the sending apparatus and pull a lever. By using two swinging sections of tube, one of which is always in line with the main tube, the apparatus is ready at all times to receive a carrier.

In connection with the sending apparatus, a time lock is used to measure and determine the time interval between the dispatching of carriers; in other words, to prevent carriers being dispatched too frequently. The period varies from six to fifteen seconds, depending upon the length of the line. The time lock is found necessary to prevent the collision of carriers and to give the receiving apparatus time to operate. The time lock consists of a dash-pot filled with oil and arranged to lock the sending apparatus, except when the piston of the dash-pot is at the bottom of its cylinder (see *Fig. 5*).

If our receiving station be located at the open end of the tube, then we must have some form of receiving apparatus to stop the carriers without shock when they arrive. For this purpose we have in our system what we term an open receiver. It consists of a section of tube about 4 feet long, closed at one end by a sluice gate and attached to the end of the main line. The air flows out through slots in the tube just before it reaches the receiver. When a carrier arrives it runs into this closed section of tube which forms an air cushion. The compression of the air by the stoppage of the carrier serves to operate a small valve, which causes the sluice gate to be raised by a cylinder and piston located above it. When the gate raises the carrier is forced out on to a receiving table, the pressure in the tube being just sufficient to do this. The gate is automatically closed after the carrier has been discharged (see *Fig. 1*).

If our receiving station be located at any other point on the line of the tube we cannot use this form of open receiver, for the pressure in the tube is so high, as shown on the diagram, that the air would escape with great force, hence we must

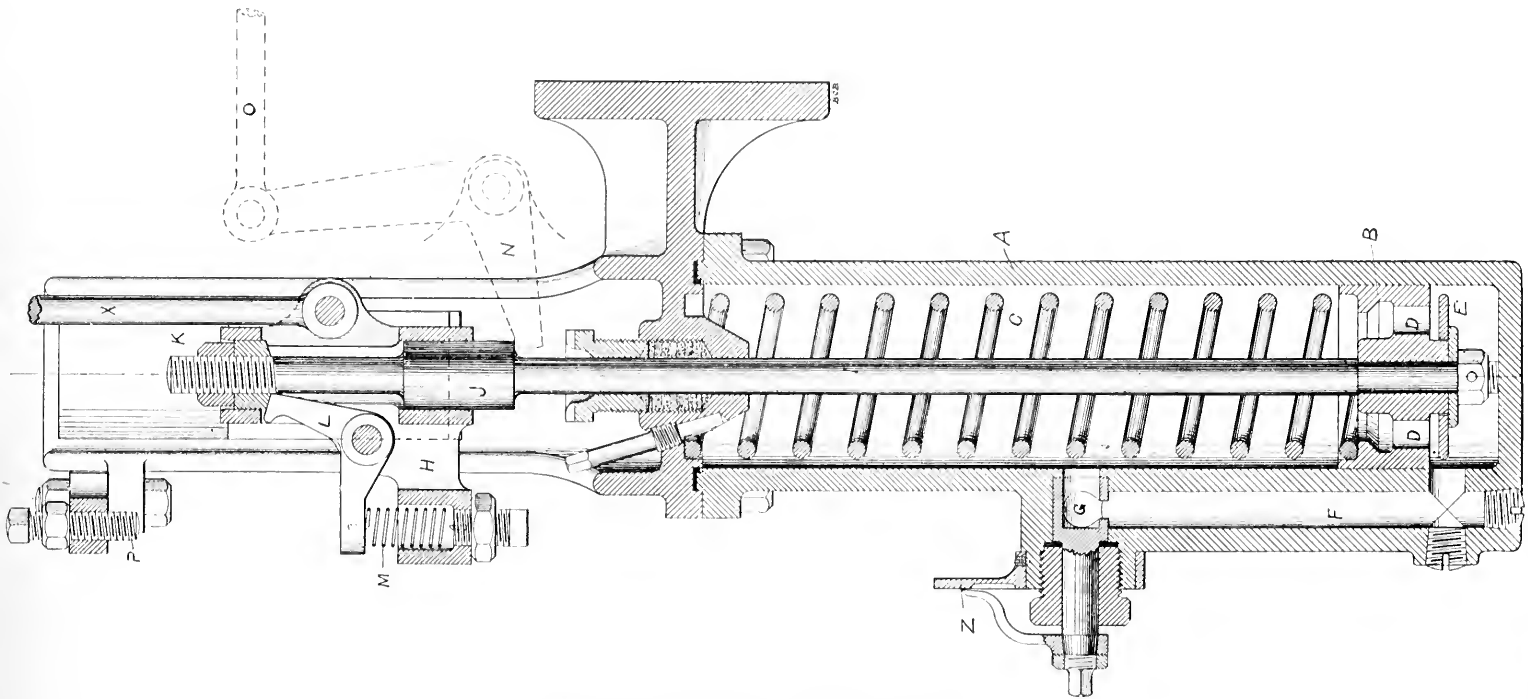



FIG. 5.—Time-lock for sending apparatus.

use what we term a closed receiver, consisting of a section of tube forming a receiving chamber and air cushion that can be placed in line with the main tube to receive the carrier, and then moved out of line with the main tube to discharge the carrier, the end of the main tube being closed during this displacement. The receiving chamber is mounted upon trunnions, and is swung out and into line with the main tube automatically by means of a cylinder and piston set into operation by the arrival of a carrier (see *Fig. 2*).

At intermediate stations on the main line of tubes we sometimes place an automatic receiving apparatus that will stop all carriers passing through the tube, and discharge those intended for that station, while all others are sent on in the tube. This is accomplished by placing various sized metal discs upon the front end of the carriers and having electric contact points at each of the stations set at graduated distances apart to correspond with the sizes of discs on the ends of the carrier. When a carrier arrives at a station where its disc is of the proper diameter to span the distance between the contact points, and thereby close the electric circuit, then that carrier will be discharged from the tube; but if the disc is too small to span the distance between the contact points, then the carrier will pass on in the tube to the next station, and so on.

Intermediate stations are usually supplied with cut-out switches, so that carriers can be sent directly past the station without entering it. These switches are moved by air pressure, controlled electrically from the nearest station (see *Fig. 6*).

There is no part of this system that has been the object of more thought and study than the carrier that contains the mail or other material to be transported. It is made of a seamless steel tube $23\frac{1}{2}$ inches long, closed at the front end by a sheet metal head and buffer, and closed at the rear end by a hinged cover provided with a lock (see *Fig. 7*).

The body of the carrier is about an inch smaller than the tube through which it travels, the space between the body of the carrier and the surface of the tube being filled by two

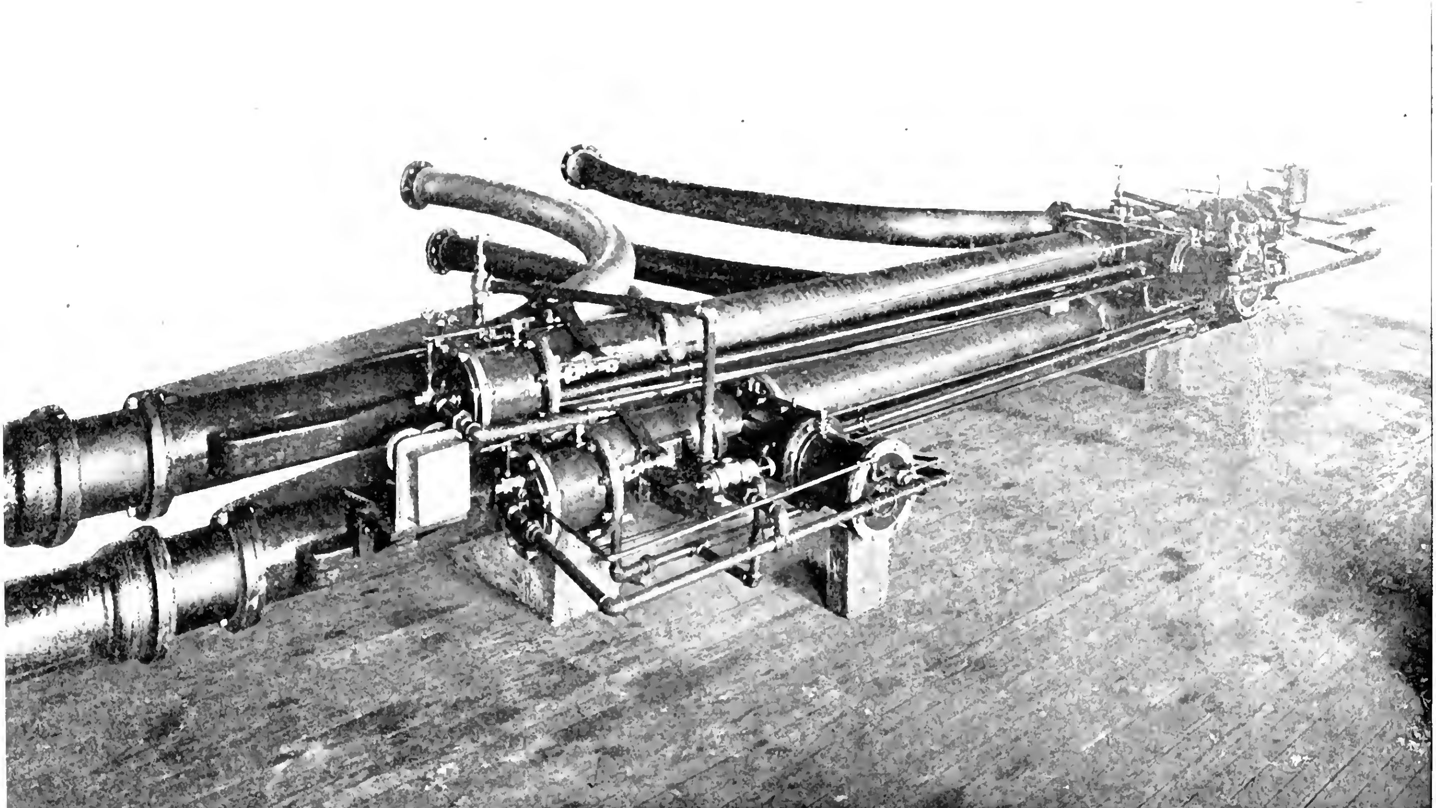


FIG. 6.—Set of cut-out switches for eight-inch pneumatic tubes.

fibrous rings that serve not only to prevent the escape of air past the carrier, but as wearing surfaces to slide on the lower side of the tube. These bearing rings are made of cotton fiber, and they will endure until the carrier has traveled about five thousand miles, when they become worn

1 2 3 4

FIG. 7.—(1) Carrier used in the Berlin system; (2) Largest carrier used in the London system; (3) Six-inch carrier used in the first Philadelphia system; (4) Eight-inch carrier used in New York and Boston.

so small that they have to be replaced by new ones. A carrier weighs $13\frac{3}{4}$ pounds, and will contain 600 ordinary letters.

The tubes used in all the circuits thus far constructed are of cast iron bored accurately upon the interior, except bends, which are made of seamless brass tube. The iron

tube is cast in 12-foot lengths, with a bell upon one end, similar to water and gas pipes. A counter bore is turned in the bottom of each bell, into which the machined end of the adjoining length fits closely. The joints are made by yarn and lead caulked in the usual manner.

Where short bends have to be made in the tube for the

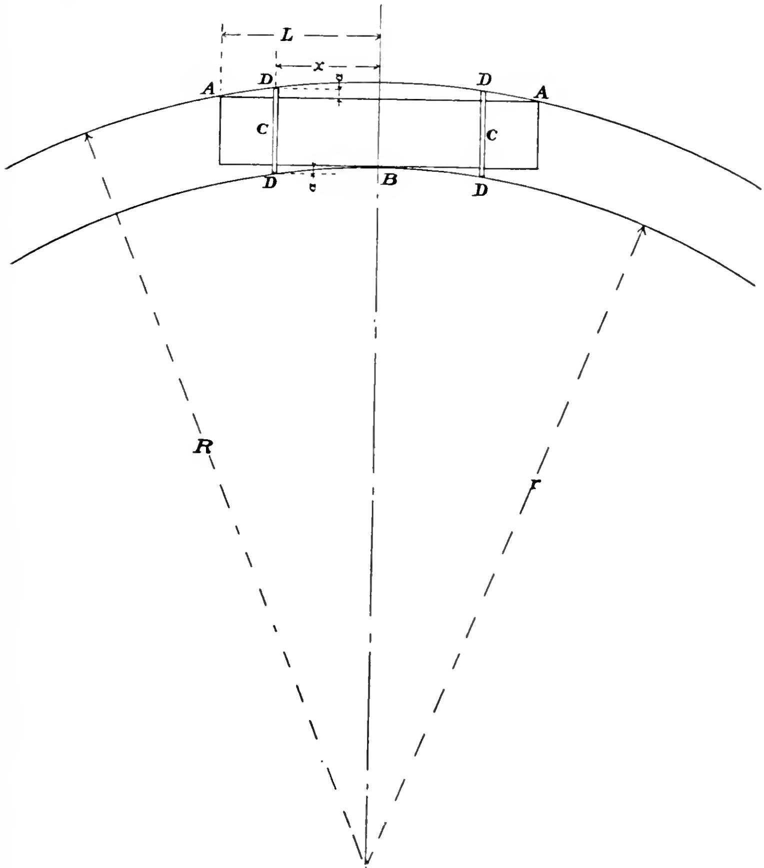



Fig. 8.

purpose of turning corners in the streets, entering buildings, etc., brass tubing is used bent to a radius of twelve times the diameter of the tube, or a radius of 8 feet for an 8-inch tube. A uniform radius is always used, for it facilitates manufacture.

In order to maintain a uniform and circular cross-section of the tubes during the process of bending, they are filled with resin.

The location of the bearing rings on the body of a carrier also has an important relation to the bends in order to give a carrier of maximum capacity. Having determined the length and diameter of the carrier body, we place the bearing rings not on the ends, but at a point where, in passing through a bend of minimum radius, the corners and center of the carrier and the bearing rings will touch the walls of the tube at the same time. This can best be explained by referring to *Fig. 8.* The rings *C C* are so placed that in passing through the bend the ends of the carrier touch the outer circumference of the tube at *A A*, at the same time that the body of the carrier touches the inner circumference at *B*, and the rings touch both inner and outer circumferences at *D D D D*.

To manufacture the tubes, brass bends, carriers, sending and receiving and other apparatus used in the system, a factory has been erected at Tioga and Memphis Streets, Philadelphia. Much of the machinery used in the various processes of manufacture has been especially designed for the purpose, and most noteworthy, perhaps, are the machines for boring the cast-iron tubes. The tubes are bored in a vertical position, for two reasons: (1) It economizes space. (2) The chips fall away from the cutters.

The boring machines are placed upon galleries about 11 feet above the floor. The bell ends of the tubes are clamped to the machines and rest on a pedestal on the floor below. The boring is done by six cutters attached to a head that is mounted on the lower end of a vertical boring bar. The bar is revolved by gearing and fed downward by a screw attached to the cutter head and extended downward through the center of the tube being bored. The feed screw does not revolve, but is drawn downward by a nut attached to the pedestal on which the tube is supported. The nut is revolved by gearing and a rope belt driven from the machine above. When a tube is placed in the boring machine the feed screw is pulled up through it and attached

to the cutter head. The boring bar simply serves to revolve the cutter head and not to guide it. The cutter head is guided by four hardwood blocks that fit the finished bore of the tube closely. The pull of the feed screw also helps to keep the cutter head in place. The cutters are flat pieces of steel, with a cutting edge at 45° with the axis of the tube. The angle of the cutter tends to make the cutter head follow the core of the tube. After the bore is finished another head is attached to the bar, which makes the counter bore at the bottom of the bell.

A special machine has been designed for bending the brass tubes, consisting of three rolls, one of which is adjustable. This operation of bending is one that requires much experience and skill on the part of the operator.

*Locating Obstructions.*—You will, perhaps, be interested in an experiment that we made in Philadelphia two years ago to locate a carrier that became lodged in one of the tubes.

The Philadelphia line was laid in the winter season, and before the trench was back-filled the loose earth became frozen, and we were obliged to put it into the trench in that condition; consequently, when the ground thawed the tubes settled and one of them was broken. For a long time this break did not obstruct the passage of carriers, but eventually one of the broken ends settled down more than the other and caught one of the carriers, blocking the entire line. We had no means of knowing where the break was located, and to excavate the entire distance between the stations involved great expense and annoyance. I made several attempts to locate it by the fall of pressure, etc., but was not satisfied with the results, so decided to try a method of locating by the velocity of sound.

The plan was to disconnect the terminal apparatus at one of the stations, fire a pistol into the tube, and note the time that elapsed between the discharge of the pistol and the return of the sound as an echo reflected back from the obstructing carrier; then, knowing the velocity of sound, a simple calculation would give us the distance from the station to the carrier.

I had a rough chronograph constructed, using a pulley

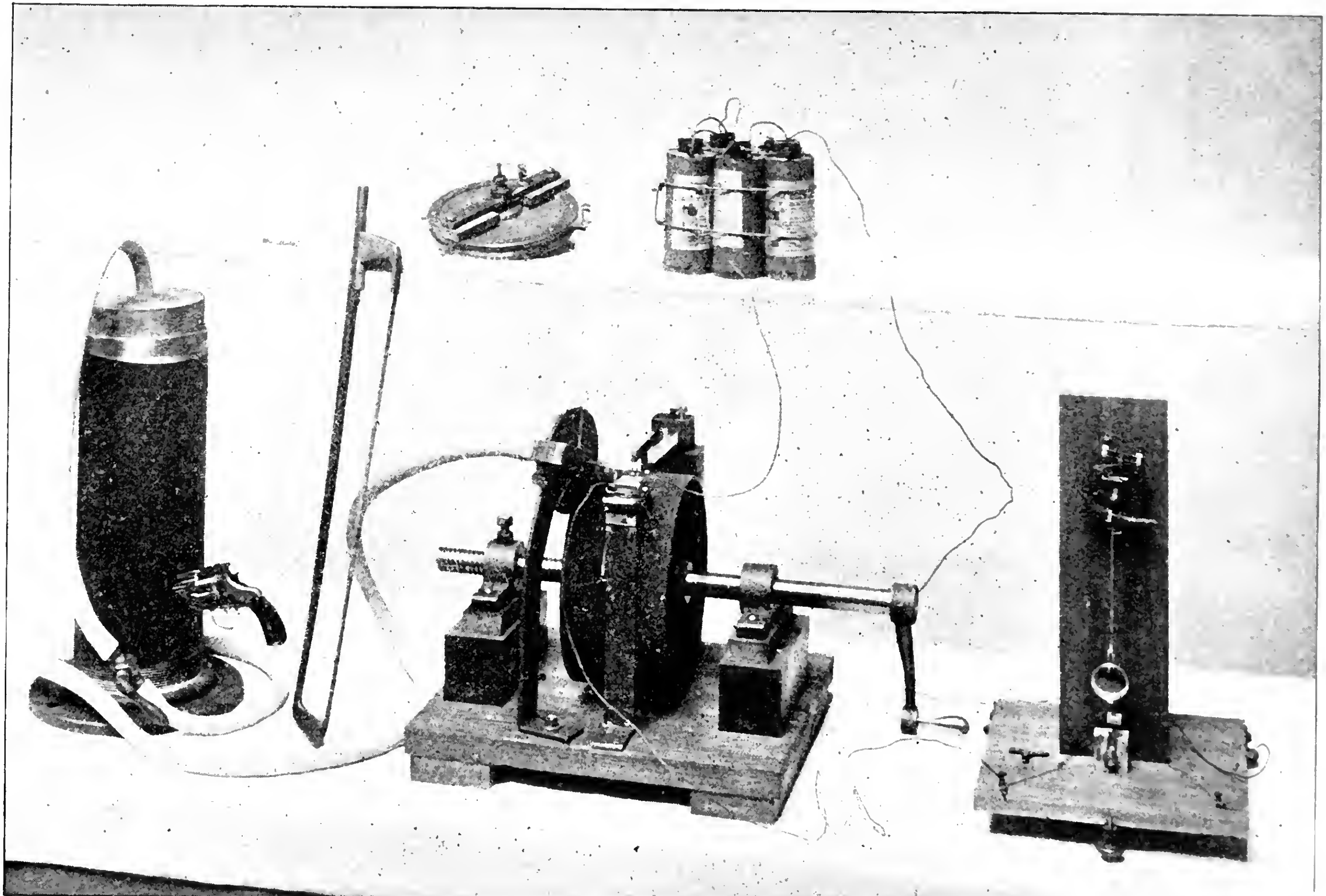


FIG. [illegible]—Cl[illegible] used in Philadelphia for [illegible]

for a drum, mounted upon a horizontal shaft with a crank for rotation and a screw to give longitudinal motion (see *Fig. 9*). Time was measured by the beats of a clock-pendulum, recorded on the chronograph drum by a stylus which moved under the pull of an electro-magnet at each beat of the pendulum. The pendulum was arranged to close an electric circuit in the usual manner by swinging through a globule of mercury. In addition to the clock, a tuning-fork was used to measure time by the number of waves traced on the smoked surface of the drum. For the measurement of small fractions of a second the tuning-fork is more accurate and convenient than a clock, but when the period extends over several seconds the work of counting thousands of small waves becomes very laborious.

I selected a fork tuned to 512 vibrations per second, which enabled me to measure to $\frac{1}{1000}$ of a second with a very small error. In fact, with a little care it was possible to measure to $\frac{1}{5000}$ of a second.

The fork was arranged in a horizontal position, having a horse-hair cemented to one prong, which traced a sinuous line on the drum as the latter was turned. The sound of the pistol discharge was recorded by a stylus attached to the end of an aluminum arm that rested against a rubber diaphragm. A chamber in the rear of the diaphragm was connected to the end of the pneumatic tube by a piece of rubber hose which conveyed the sound waves from the tube to the chronograph. A cock was placed in the middle of the hose and partially closed before the pistol was discharged to prevent too great distention of the diaphragm by the direct impact of the sound-waves. The cock was opened by an attendant after each discharge and before the echo returned, in order that the feeble sound-waves of the echo might not fail to be recorded.

The muzzle of the pistol was inserted into the tube through a small hole in the side, the end of the tube being closed by a funnel to which the rubber hose was connected.

When the apparatus was properly adjusted a measurement was taken in the following manner: The clock was started, the tuning-fork set in vibration by striking with a

mallet or by bowing, and the drum rotated by hand; then the pistol was discharged and the cock in the rubber hose opened. A few moments only were required to count the waves of the tuning-fork and from them compute the time.

The experiments were usually repeated several times to eliminate errors. Five experiments gave the following results:

| | | |
|---|---|---|
| 1 | 2·791 | seconds. |
| 2 | 2·794 | " |
| 3 | 2·793 | " |
| 4 | 2·793 | " |
| 5 | 2·794 | " |
| Mean | 2·793 | " |

A thermometer was placed in the ground beside the pipe and the temperature found to be 39°. It was assumed that this was the temperature of the air in the tube. The velocity of sound at 32° was assumed to be 1,093 feet per second, and the increase of velocity for each degree of temperature to be 1·12 feet; this gives at 39° the velocity of 1,101 feet per second.

In 2·793 seconds the sound would travel 3,075 feet, which locates the carrier at 1,537 feet from the instrument. This indicated that the carrier was lodged 100 feet east of Seventh Street, and workmen were ordered to excavate at that point. Before reaching the tube, air was heard escaping from the break, and the carrier was found almost exactly where it had been located by the instrument.

It is impossible to say what the limits of the method are so far as distance is concerned, but experiments of Regnault show that the report of a pistol is no longer heard at a distance of

| | | | | | | |
|---|---|---|---|---|---|---|
| 1,159 | metres | in a | tube | 0·018 | m. | in diameter. |
| 3,810 | " | " | " | 0·300 | " | " |
| 9,540 | " | " | " | 1·100 | " | " |

But the same sound-waves will vibrate a sensitive diaphragm at distances of 4,156, 11,430, and 19,851 metres respectively.

# AN INSTRUCTIVE MECHANICAL FAILURE.

By WILFRED LEWIS,
Member of the Institute.

The discovery of broad general principles is constantly removing from the field of research the hallucinations that formerly engrossed the activities of many hands and minds, and nothing illustrates more clearly the value of technical training than the check which it imposes upon the pursuit of mechanical follies. An example of this may be noted in the lives wasted on the problem of perpetual motion that might have been saved for useful work by an earlier exposition of the conservation of energy. That a few are still engaged in the hopeless task is clearly due to the imperfect dissemination of this great principle; but since the time of Redheffer, the number of these misguided enthusiasts has steadily diminished.

The craze for perpetual motion probably reached its height in 1812, when, as described by Dr. Henry Morton, in this *Journal* for April, 1896, Redheffer applied to the Legislature of Pennsylvania for a grant of funds to carry on and perfect his great invention. Instead of acceding to this modest request, the more prudent course was adopted of appointing an investigating committee, which was graciously allowed to view the wonder of the age at a respectful distance, through a glass case, but closer inspection was not invited. Nevertheless, one glance was sufficient for the keen observation of young Coleman Sellers,* as the result of which a duplicate model was soon made and exhibited with very depressing effect upon the pretensions of Redheffer, whereupon he retired to private life.

There was no refuge then for an unmasked deceiver behind the bars of a fantastic terminology known only to himself. Doubtless, people liked to be humbugged then as they do now; but no genius had ever conceived the possibility of success in a series of occult scenic effects

* Afterwards the father of our esteemed contemporary, Dr. Coleman Sellers.

purporting to illustrate a confused mummery of terms. This triumph was reserved for a later period, when satiated reason seemed to crave diversion. It is not my intention, however, to reckon with the philosophy of the Keeley motor as expounded by its alleged inventor, nor to deal with anything beyond the pale of common sense.

But, although perpetual motion has been relegated to the bottomless pit of folly by all minds capable of grasping the truth which it violates, there are other truths equally well established as laws of nature, against which the folly of would-be inventors is still beating. It is not surprising that in 1812, while the philosophy of energy was in process of evolution and before the great doctrine of its conservation had been clearly established, intense interest should have been awakened in the reputed discovery of perpetual motion. There was then some hope of success and the promise of fame and fortune to the triumphant inventor. But, at the close of this century of scientific progress, it is amazing to witness an assault upon principles formulated long before the conservation of energy, and clearly elucidated in modern text-books on natural philosophy.

Inertia is an inherent property of matter, and Newton's first law of motion, which is really a law of inertia, asserts that a body at rest remains at rest, and a body in motion continues in motion and in a straight line, unless it is deflected by some controlling force.

Newton's laws also assert the relations between force, mass and acceleration, and define force in terms of the acceleration produced upon a given mass in a given time. Physical forces are thus made comparable to the force of gravity, and the measure of force is expressed in acceleration or change of velocity. The actual velocity has nothing to do with it except as an index to the rate of change in deflected or curvilinear motion, and, in every case, the change of velocity in any given direction is the true measure of the force acting in that direction.

The laws of gravity and inertia have for centuries been known to hold the planets in their orbits, and the observed effect of these laws on the motion of matter in space has

served to detect the existence of unseen matter and point to its actual discovery, thus demonstrating the universality of natural law and its perfect precision of action in the boundless depths of space. Here the problems are grand and complex, while the data for their solution are often incomplete and uncertain, requiring the exercise of rare judgment and great ability; but in dealing with terrestrial bodies, where motion is necessarily more limited and restrained, the effect of inertia is felt directly in the restraining material, and the data for its determination are so definite and clear that no room is left for doubt or speculation of any kind. Yet on the 9th of March, 1897, we find the U. S. Patent Office actually granting patents for an alleged improvement in balancing locomotive driving-wheels on the pretension that the translation of the wheel along the rail has an important bearing, hitherto overlooked, upon the inertia of the revolving parts. Such action totally ignores the well-known fact that the revolving parts never give any trouble in balancing, and present no difficulty whatever to be overcome, and naïvely assumes the existence of an imaginary fault for the purpose of having something to correct, while the real difficulty of balancing the reciprocating and revolving parts together seems to be unheeded or unknown.

It would hardly be worth while to give an idea of this kind more than passing notice, had it not been so persistently entertained and developed, and did it not appear to be gaining credence to a remarkable extent.

The amount of time, money and enthusiasm spent in this direction can be appreciated only after an examination of the apparatus designed to sustain the contention raised, and a review of the arguments and diagrams offered in its support.

All of this is so ingenious, so plausibly presented and throws such interesting and unexpected side lights upon a subject not commonly studied, that it is hoped its exposition may compensate in some measure for the complete failure of the original purpose to improve the balance of locomotive driving-wheels.

The promoter of this laudable scheme was unfortunately misguided in his perception and interpretation of facts, but so confident was he of the success of his labors that he applied, not for a grant of funds from the Legislature, like the over-reaching Redheffer, but for a report from an investigating committee of the Franklin Institute.

It has been the privilege of the writer to serve on this committee, and, with the generous approval of the applicant, who desires the truth to be known, hoping that others may benefit by his experience, the story of this failure in balancing may now be told.

The alleged improvement in balancing a locomotive driving-wheel is shown and described in three U. S. patents

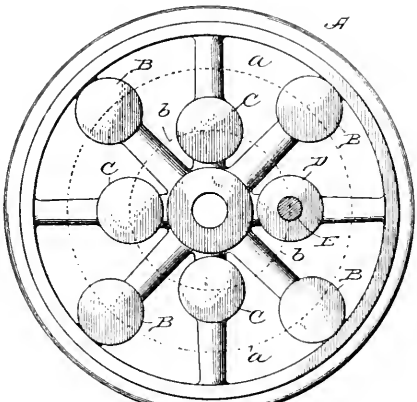



FIG. 1.

granted to Philip Z. Davis, March 9, 1897, and numbered consecutively 578,597–8–9. In the first-mentioned patent a number of weights are disposed, as shown in *Fig. 1*, four of which, including the crank pin, are in the crank circle 90° apart, while four more are in an outer circle 90° apart, and on radial lines 45° from the inner set. The weights, *C*, in the crank circle, are described as being each equal to the weight of the boss *D* and the pin *E*, while the equal weights *B*, in the outer circle, are said to be varied in weight with the ratios between the diameters of the crank circle, the balancing circle and the rolling circle, but in what manner does not appear.

In this arrangement there is but one weight opposed to the crank pin, all the other weights being made to balance each other.

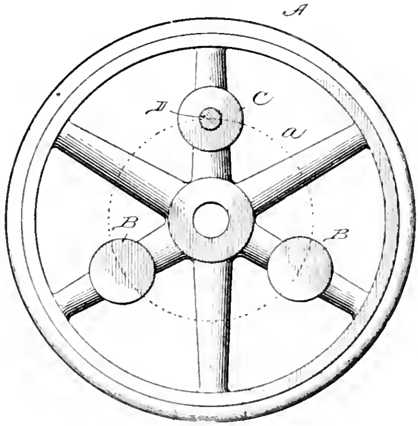



FIG. 2.

In the second patent, No. 578,598, there are two weights opposed to the crank pin, as shown in *Fig. 2*, 120° apart, and this arrangement is put forward as the most practical form of the invention.

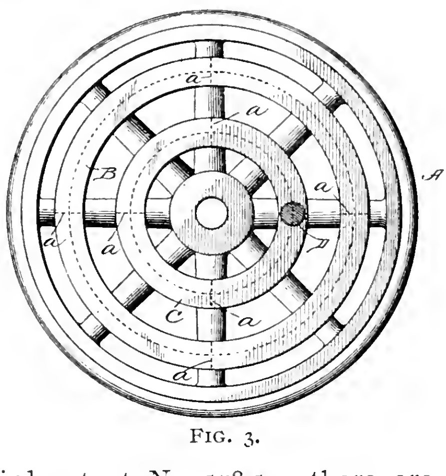



FIG. 3.

In the third patent, No. 578,599, there are, as shown in *Fig. 3*, two balancing rings, one in the crank circle and one outside, and apparently there is nothing directly opposed as a counterweight to the crank pin.

In all cases the wheels are assumed to be in running balance on their centers, and to the peculiar arrangements of counterweights is ascribed the virtue of maintaining this balance while the wheels are running on a track.

It cannot be denied that the wheels, balanced as described, will run in perfect balance on a straight track just like any other balanced wheels; but the imputation is that the usual method of balancing is defective, and adopting this fiction as an hypothesis, a curious philosophy is developed to explain a shadow that was never cast.

The inventor claims a system of balancing by which he obtains a perfect balance for all revolving parts, and an improved balance for the reciprocating parts of a locomotive driving-wheel, but his argument is all with reference to the revolving parts, and as nothing is adduced to show any improvement in the balance of the reciprocating parts, our attention will be confined to the revolving parts only. He also claims that, by using two counterweights disposed as shown in *Fig. 2*, he has overcome the difficulty in balancing locomotive drivers, and his philosophy asserts that any weight attached to a locomotive driving-wheel must have its force and effect computed from its true center of rotation, which is the point of contact of wheel and rail for the motion of rotation and translation combined.

To demonstrate in a practical way this fundamental contention that the motion of translation cannot be neglected in computing the effect of a counterweight, and to show that a wheel balanced by two weights for rotation around its center is not in balance when the motion of rotation and translation are combined by rolling on a track, the testing machine illustrated in *Fig. 4* was designed and built.

This machine consists of a circular track, about 3 feet in diameter, upon which a pair of counterweighted discs is mounted to run on horizontal axles, while the axles themselves are driven by a vertical shaft in the center of the circular track. This track is mounted on three weighing levers connected at the center to another lever, which in turn is connected to the elastic finger of a recording pencil. The vertical shaft, which drives the pair of discs, carries a large

paper drum, upon which the recording pencil can be allowed to act. The axles which carry the two discs are hinged near the center, leaving the discs perfectly free to press upon the circular track, and any variation in this pressure is shown by the movement of the recording pencil.

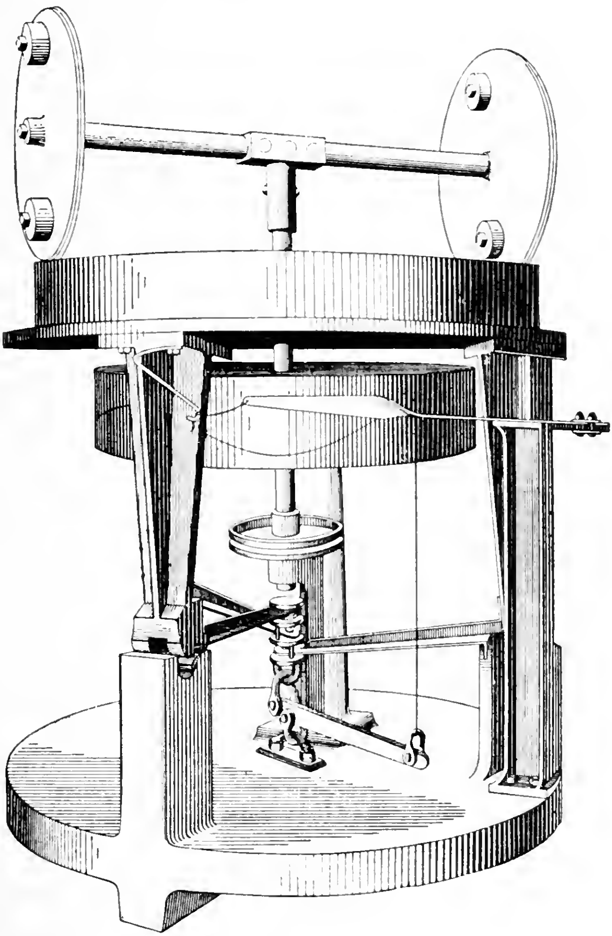


FIG. 4.

When the discs are counterweighted, as shown in *Fig. 4*, and driven at a moderate speed, the recording pencil will be set in vibration, making two complete movements for every

rotation of the disc, and, as the speed increases, the amplitude of the vibrations becomes rapidly greater. On the other hand, when the discs are counterweighted at three points, as shown in *Fig.* 2, there is no vibration of the recording pencil at any speed, but the position of the pencil changes, showing more and more pressure on the track as the speed increases.

The remarkable results indicated by this ingenious mechanism have been supposed, by some observers, to substantiate the contention that the accepted philosophy of inertia, as commonly applied to counterweights in rotating bodies, is all wrong when applied to bodies which combine a motion of rotation with that of translation. In other words, "that the force and effect of the counterweights must be computed from their true center of rotation, which is the point of contact of wheel and rail."

This is put forward as a new and original method, differing sensibly in its results and leading to a decided advance in the perfection of balancing a locomotive driving-wheel.

There is, however, an obvious difference between the movement of the experimental discs and that of a locomotive driving-wheel, as it commonly occurs on a straight track. The former rotate about an axis which is itself revolving about another axis at right angles, while the latter simply rotates about an axis in motion which remains parallel to itself. One gyrates in two planes of motion, while the other moves only in one, and this important difference furnishes the key for explaining the observed facts as natural results without the aid of the pretended new theory of balancing.

It cannot be admitted as possible that a wheel in running balance on a fixed axis will be out of balance on an axis moving parallel to itself, nor that "translation and rotation combined" on a straight track can have any effect whatever upon the balance of the revolving parts. The effects observed in the experimental apparatus are demonstrably due to gyroscopic action, and to show this in a practical way we are indebted to Mr. Hugo Bilgram for the instrument illustrated in *Fig.* 5.

It is simply a disc mounted upon an axis in a forked handle, to be spun with a cord like a top, and held in the hand. Two or three counterweights may be attached to the disc, giving, in either case, a perfect running balance.

Now, while the disc is spinning, it is found that the instrument can be moved in any direction parallel to itself, with as much freedom as when the disc is at rest; but attempt to change the direction of the axis, and a decided resistance is at once encountered.

If the disc is spinning rapidly and the direction of the

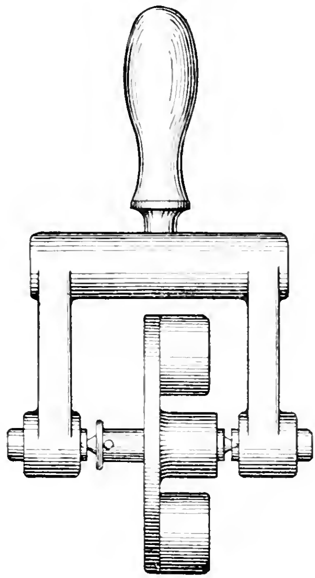


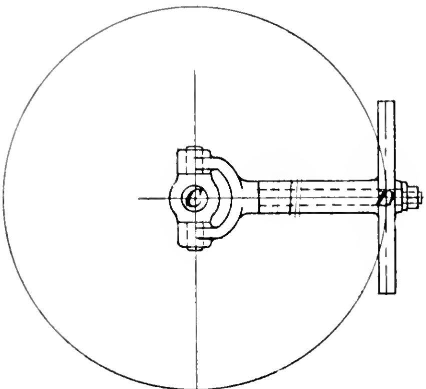
FIG. 5.

axis is suddenly changed, the instrument twists in the hand even when a strong grip is taken to prevent it. This phenomenon occurs whether two or three counterweights are used, but a decided difference in effect is also noticed. When two counterweights are used, the twisting referred to is accompanied by a series of impulses depending upon the speed of rotation, but when three are used the twist is steady and without pulsations.

This experiment is interesting and instructive, not because it exposes the futility of the elaborate testing ma-

chine to establish the fundamental contention in this new philosophy, but because it suggests the possibility that out of its failure and by its means a new and important principle of motion may accidentally have come to light. It is not surprising that the gyroscopic effect of three counterweights should be steadier than that of two, but it is at first surprising that three weights should run as steadily as four

FIG. 6.



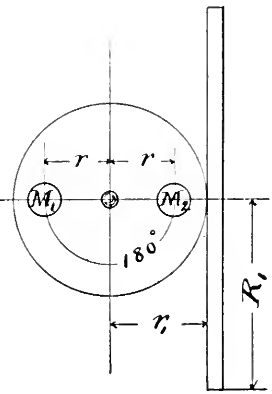




FIG. 7.

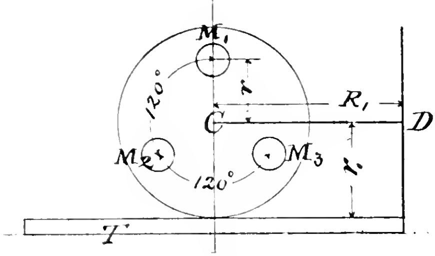



FIG. 8.

or six in two planes of motion; and a rigid analysis of the problem discloses the curious fact, which may be stated as a principle, that in gyroscopic effect three weights, disposed as shown in *Fig. 2*, 120° apart, are equivalent to a ring of the same radius and weight. This may or may not be a new discovery, but it leads to such a clear understanding of the

gyroscope, and explains so fully the observed effects in the testing machine experiments, that it is thought advisable to give the analysis in detail, after which the fallacy in the argument "from point of contact with rail" will be considered.

Given the disc $D$, *Figs.* 6, 7 and 8, radius $r$, mounted on a horizontal axis and driven on the circular track $T$, radius $R$, by a vertical shaft $C$, normal to the plane of the track and passing through its center, the disc being free to press upon the track, but restrained by its axis, or by a counterweight, against centrifugal force about the center $C$.

(1) To find the effect on the track of two equal masses, $M_1$ and $M_2$, *Fig.* 7 at a distance $r$ from the axis and 180° apart.

(2) To find the effect of three equal masses, $M_1$, $M_2$ and $M_3$, *Fig.* 8, 120° apart.

Let $v_1$ = velocity in feet per second of the center of the disc $D$ about the vertical axis $C$.

$v$ = velocity of any other point in the same direction at a distance $x$ above the track.

$R_1$ = radius $C\,D$ in feet at which the center of the disc $D$ revolves about $C$.

$r_1$ = radius of the disc $D$ in feet.

$r$ = radius of the masses $M_1$, $M_2$ and $M_3$ to be considered.

$\omega$ = angular velocity of the axis $C\,D$.

$\beta$ = angular velocity of the disc $D$ about its axis $C\,D$ =

$$\omega \frac{R_1}{r_1} = \frac{v_1}{r_1}$$

$a_1$ = acceleration normal to the plane of the disc $D$ due to the velocity $v_1$.

$a$ = acceleration normal to the plane of the disc $D$ due to the velocity $v$.

From the conditions of the problem it is evident that the velocity $v$, of any point in the disc $D$ at a distance $x$ above the track $T$, may be expressed by the equation

$$v = \frac{x\,v_1}{r_1} \qquad (1)$$

The center of the disc $D$ moves about $C$ with the velocity $v_1 = \omega R_1$ and its normal acceleration is given in the well-known expression for circular motion,

$$a_1 = \omega^2 R_1 = \omega v_1 \tag{2}$$

Here $a_1$, $\omega$ and $v_1$ are taken in a plane normal to the vertical axis $C$, and since $\omega$ is constant for all points in the disc $D$, the normal acceleration $a$ for any point in the disc must depend upon its velocity $v$ and be expressed by the general equation

$$a = \omega v = \omega v_1 \frac{x}{r_1} = a_1 \frac{x}{r_1} \tag{3}$$

The force $F$ developed by a mass $M$ under the acceleration $a$ is $F = M a$, but since the balanced masses are all assumed to be equal, they may be more conveniently treated as unit masses, for which we have simply $F = a$.

At the center of the disc $D$ the normal force $F_0$ for a unit of mass at that point becomes

$$F_0 = a_1 = \omega v_1 \tag{4}$$

and for any other point in the disc at the distance $x$ above the track,

$$F = \frac{x}{r_1} F_0 \tag{5}$$

In the case shown by *Fig.* 7, two equal masses $M_1$ and $M_2$ are assumed at the distance $r$ from the center of the disc $D$ and 180° apart.

For $M_1$ we have $x = r_1 + r$ and $F_1 = \left(1 + \frac{r}{r_1}\right) F_0$

For $M_2$ we have $x = r_1 - r$ and $F_2 = \left(1 - \frac{r}{r_1}\right) F_0$

The moment $K_1$, of the force $F_1$ at the distance $r$ above the driving trunnions $C$ is

$$K_1 = r F_1 = r \left(1 + \frac{r}{r_1}\right) F_0$$

and the opposing moment of the force $F_2$ is

$$K_2 = -r F_2 = -r \left(1 - \frac{r}{r_1}\right) F_0$$

The algebraical sum of these moments, or the resultant moment $K$, is therefore

$$K = K_1 + K_2 = \frac{2 r^2}{r_1} F_0 = 2 r^2 \omega \beta \tag{6}$$

Now, when the masses $M_1$ and $M_2$ turn through 90° and stand for an instant at the same height $r_1$ above the track $T$, it is evident that the resultant moment $K$ is zero, and that as the disc $D$ runs on its circular track, $K$ must vary by the amount $2 r^2 \omega \beta$ twice for each rotation of the disc. Dividing the moment $2 r^2 \omega \beta$ by the arm $R_1$ through which it acts, the variation in the pressure on the track may be expressed by the equation

$$\Delta P = \frac{2 r^2 \omega \beta}{R_1} \tag{7}$$

Since the center of gravity of the masses $M_1$ and $M_2$ is always in the center of the disc $D$, it is evident that the sum of the forces $F_1 + F_2 = 2 F_0$ is constant, and deducting $F_0$ from $F_1$ and $F_2$ respectively, we have the components $F_1 - F_0$ and $F_2 - F_0$ causing moments about $C$, and the central force $2 F_0$ along the radius $C D$.

$$F_1 - F_0 = \frac{r}{r_1} F_0 \text{ and } F_2 - F_0 = -\frac{r}{r_1} F_0$$

the first of which acts at the distance $r$, causing the moment

$$\frac{r^2}{r_1} F_0$$

while the second acts at the distance $-r$, causing the same moment, the sum of which is

$$2 \frac{r^2}{r_1} F_0 = 2 r^2 \omega \beta$$

as given in equation (6).

For any arrangement of equal balanced masses, the sum of the moments $K$ can therefore be expressed as the sum of the components $y^2 \omega \beta$, in which $y$ is the vertical distance of

each point of mass above or below the plane of motion for the axis *C D*.

In other words, we have

$$K = \Sigma\, y^2\, \omega\, \beta \tag{8}$$

by which the analysis for three or more masses can be easily followed.

In *Fig. 3* there are three unit masses, $M_1$, $M_2$ and $M_3$, at the distance $r$ from the center and 120° apart. $M_1$ acts at the distance $r$ above the center, $M_2$ and $M_3$ each act at the distance $r$ *sin.* 30° below the center, and the sum of the moments $K$ is, by equation (8),

$$K = (y_1^2 + y_2^2 + y_3^2)\, \omega\, \beta \text{ or}$$

$$K = \left(r^2 + \frac{r^2}{4} + \frac{r^2}{4}\right) \omega\, \beta = 1{\cdot}5\, r^2\, \omega\, \beta \tag{9}$$

Now, if we let these masses keep the same relative positions and be shifted through an angle $\theta$, we have

$$y_1 = r\, cos.\, \theta,\ y_2 = r\, sin.\, (30° - \theta) \text{ and } y_3 = r\, sin.\, (30° + \theta)$$

$$y_1^2 = r^2\, cos.^2\, \theta,\ y_2^2 = r^2\, sin.^2 (30° - \theta) \text{ and } y_3^2 = r^2\, sin.^2\, (30° + \theta)$$

$$sin.^2\, (30° - \theta) = \tfrac{1}{4}\, cos.^2\, \theta - \sqrt{{\cdot}75}\, sin.\, \theta\, cos.\, \theta + {\cdot}75\, sin.^2\, \theta$$

$$sin.^2\, (30° + \theta) = \tfrac{1}{4}\, cos.^2\, \theta + \sqrt{{\cdot}75}\, sin.\, \theta\, cos.\, \theta + {\cdot}75\, sin.^2\, \theta$$

Therefore $y_1^2 + y_2^2 + y_3^2 = 1{\cdot}5\, r^2\, (sin.^2\, \theta + cos.^2\, \theta)\, \omega\, \beta = 1{\cdot}5\, r^2\, \omega\, \beta$, as shown by equation (9) for the original position.

With three unit masses at the same distance from the center and 120° apart, there is, therefore, no change in the resultant moment of the centrifugal forces, and for the constant pressure on the track due to these forces, we have

$$P = \frac{1{\cdot}5\, r^2\, \omega\, \beta}{R_1} \tag{10}$$

Similarly it may be shown that the total energy $E$ stored in the masses $M_1$, $M_2$ and $M_3$ is constant, and for this the value is expressed by the equation

$$E = 3\, \omega^2\, R_1 + 3\, \beta^2\, r + 1{\cdot}5\, \omega^2\, r \tag{11}$$

The sum of the centrifugal forces $F = F_1 + F_2 + F_3$ is

also constant and equal to 3 $F_0$, and it must therefore be concluded that three equal masses 120° apart, as shown in *Figs.* 2 and *8*, will run as steadily as a homogeneous ring without variation in pressure on the track or periodic impulses of any kind.

In the above analysis, the disc $D$ has been treated as a very thin sheet of metal, and the masses $M_1$, $M_2$ and $M_3$ as points of weight in that plane, whereas the disc must have sensible thickness and the counterweights must have volume.

From the results obtained, however, the analysis is easily extended to a disc of any thickness and to weights of any size as cylinders therein.

Since three points of mass, as shown, are equivalent to a homogeneous ring of their combined mass at the same radius, it can be shown from equation (9) that a ring of unit mass at the radius $r$ will exert the moment

$$K_r = \cdot 5\ r^2\ \omega\ \beta \tag{12}$$

and from this equation it is evident that the moment $K_r$ is independent of the position of the assumed ring along the axis $C\ D$. Equation (12) therefore applies to a thin cylinder of any length, and from this the moment $K_d$ for a solid disc of unit mass will be found to be

$$K_d = \cdot 25\ r^2\ \omega\ \beta \tag{13}$$

For three cylindrical counterweights, each of unit mass, 120° apart, having a radius $r_0$ and acting at the radius $r$ from the axis $C\ D$, we have

$$K_3 = 1 \cdot 5\ r^2\ \omega\ \beta + \cdot 75\ r_0^2\ \omega\ \beta \tag{14}$$

It is thus possible to determine for any given disc, weighted as shown in *Figs. 2* and *8*, the increase in track pressure due to its speed and the curvature of the track. Obviously, if the track is straight, $\omega$ becomes zero, and there is no increase of pressure.

Referring again to *Fig. 7*, it should be observed that, although the sum of the centifugal forces $F_1 + F_2$ is constant and equal to 2 $F_0$, the total energy of motion $E$, like the track pressure, is variable. For two unit masses at the

radius $r$, this variation in energy $\Delta E$ may be expressed by the equation

$$\Delta E = 2\, r^2\, \omega^2 \tag{15}$$

and this will set up plus and minus impulses in the plane of the axis $C\,D$, parallel to the track.

A disc with two balanced masses, 180° apart, is therefore characterized while running on a curved track, by impulses upon and along the track, the latter tending to fluctuate the angular velocities $\omega$ and $\beta$, while the former simply varies the pressure on the rail.

For convenience in estimating this variation in rail pressure, equation (7) may be written in the form

$$\Delta P = \frac{2\, r^2\, \omega\, \beta}{G} \tag{16}$$

where $G$, the gauge of the track, becomes the arm of the couple.

For example, suppose a driving-wheel 6 feet in diameter has a mass of 10 concentrated at the crank pin 1 foot radius, and an equal mass at the same radius directly opposite, and let this wheel be running on a curve of 1,000 feet radius at the rate of 90 feet a second, or a little over a mile a minute, the gauge of the track $G$ being 5 feet, to find the variation in rail pressure.

Here $\omega = \frac{90}{1000} = {\cdot}09$, and $\beta = \frac{90}{3} = 30$. Substituting these values in equation (18), we have

$$\Delta P = \frac{2 \times 10 \times {\cdot}09 \times 30}{5} = 8{\cdot}4 \text{ lbs.}$$

a very insignificant amount for quite an extreme case; but this refers to one driver only, while the other driver on the same axle must have the same masses disposed at right angles to the first.

There are, consequently, four equal masses 90° apart to be considered, and referring to the general equation for the moment of centrifugal forces, $K = \Sigma\, y^2\, \omega\, \beta$, we have, when $M_1$ and $M_3$ are in a vertical line and $M_2$ and $M_4$ in a horizontal

line, at the radius $r$, $y_1 = r$, $y_2 = o$, $y_3 = r$ and $y_4 = o$. The sum of the moments $y^2 \omega \beta$ is, therefore,

$$K = 2r^2 \omega \beta \qquad (17)$$

Now, letting all these masses turn through a small angle $\theta$, we have

$$y_1 = r\ cos.\ \theta,\ y_2 = r\ sin.\ \theta,\ y_3 = r\ cos.\ \theta,\ y_4 = r\ sin.\ \theta$$

and the sum of the moments becomes

$$K = 2\,r^2\,(sin.^2\,\theta + cos.^2\,\theta)\,\omega\,\beta = 2\,r^2\,\omega\,\beta$$

as before. If the crank pins are balanced by equal masses directly opposite, it thus appears that no fluctuation in track pressure can occur from this cause even when the wheels are running on a curved track at high velocity. It is also quite apparent, by the method just employed, that this conclusion applies as well to a pair of drivers counter-weighted in the usual manner by weights near the rim instead of in the crank circle, and it cannot be doubted that the usual method of balancing a pair of locomotive driving-wheels is as perfect in effect as any of the methods claimed to be an improvement in the patents referred to.

The recognized difficulty in counterbalancing driving-wheels, on account of the counterweight being in a different plane of motion from that of the crank pin, and also on account of the inertia of the reciprocating parts, remains unnoticed, and need not be discussed. We now come to the argument "from point of contact with rail," in support of which the gyroscope has been so futilely employed.

It is claimed that the force and effect of a counterweight in a locomotive driving-wheel must be computed from its true center of rotation, the point of contact of wheel and rail for the motion of rotation and translation combined.

Since inertia forces in a given direction are invariably accompanied by a change of velocity in that direction, it is impossible to imagine how the accelerations and retardations due to rotation can be at all affected by rectilinear translation in any direction.

The addition of a constant to a variable never affects its differential, and it is clearly the difference in velocity

divided by the difference in time that measures accelerations. This, in fact, is the definition of the term; but to show more conclusively the fallacy in the argument presented, and the utter lack of any foundation whatever upon which the alleged improvement in balancing can be based, we will consider the actual path traced by a point in the driving-wheel with reference to the track.

The path traced by any point between the center and the circumference of a rolling circle is known as a prolate cycloid. A point in the crank circle *G G*, *Fig. 9*, traces the curve *C G K*, *Fig. 10*, and a point in the outer circle *H H*, *Fig. 9*, traces the curve *B I H*, *Fig. 10*, also shown to a larger scale as *B*, *B'*, *B''*, etc., *Fig. 11*. These curves are both con-

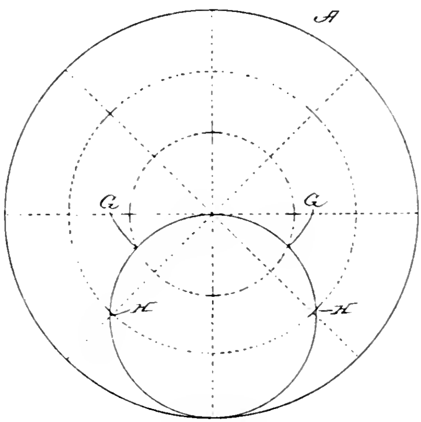



FIG. 9.

cave and convex to the track, and their points of inflection, *G G* and *H H*, where the curvature changes, have been particularly specified in the first-mentioned patent as points where there is no normal force, the argument being that while the curve is concave, the centrifugal force in the moving weight is away from the track; and while convex, the centrifugal force has a downward component upon the track. This would, undoubtedly, be true for a body moving in a prolate cycloid at a uniform rate, but it is certainly not true for the variable rate at which the body actually does move, because the inertia of the body in the line of its travel is wholly neglected.

No matter whether the center of the rolling disc or its point of contact with the rail be considered as fixed, it is perfectly clear that any point in the disc attains its maximum vertical velocity as it passes the center line, and that, consequently, on either assumption, the neutral point in the vertical forces must be on that line.

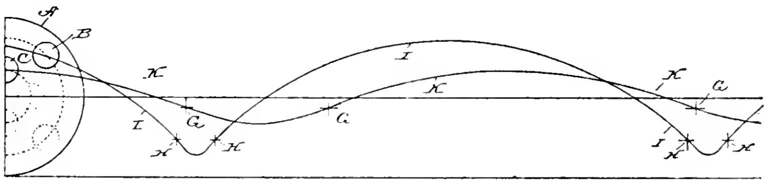


FIG. 10.

Now, if the disc is rotating about its center $O$, *Fig. 11*, at the angular velocity $\beta$, we would certainly find the vertical force exerted by a unit of mass at the point $B$, radius $r$ by the equation

$$F = \beta^2 r \tag{18}$$

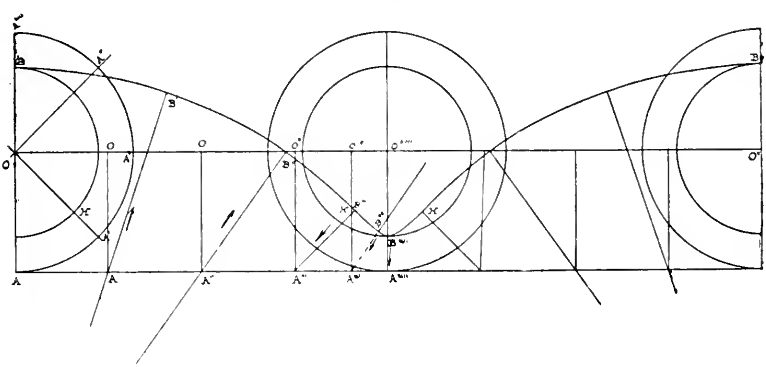


FIG. 11.

and for the point $B'''''$ we would have the same force in the opposite direction, but it is claimed that these forces should be computed from "the true center of rotation, the point of contact of wheel and rail."

Very well; let us look at the problem from the same point of view and accept without question the demonstration given in "Proctor's Geometry of Cycloids," that the radius

of curvature of the prolate cycloid at the point $B$ is expressed by the equation

$$\rho = \frac{(r_1 + r)^2}{r} \tag{19}$$

and for the point $B'''''$ by the equation

$$\rho = \frac{(r_1 - r)^2}{r} \tag{20}$$

The velocity at the point $B$ is clearly

$$v = \beta\,(r_1 + r) \tag{21}$$

and at the point $B'''''$ it is

$$v = \beta\,(r_1 - r) \tag{22}$$

A unit of mass moving with the velocity $v$ at the radius $\rho$ develops the centrifugal force expressed by the equation

$$F = \frac{v^2}{\rho} \tag{23}$$

and substituting in this equation the values of $\rho$ and $v$ for the point $B$, as given in equations (19) and (20), we have

$$F = \frac{\beta^2\,(r_1 + r)^2}{\dfrac{(r_1 + r)^2}{r}} = \beta^2\,r \tag{24}$$

and similarly for the point $B'''''$ we have, from equations (20) and (22),

$$F = \frac{\beta^2\,(r_1 - r)^2}{\dfrac{(r_1 - r)^2}{r}} = \beta^2\,r \tag{25}$$

both of which values of $F$ are identical with that found by the usual method and expressed in equation (18).

It thus appears that the centrifugal force at the points $B$ and $B'''''$ of the prolate cycloid, *Fig. 10*, is the same, whether estimated from the center of the circle or from the point of contact of wheel and rail, and, since the translation of the wheel along the rail means nothing more than a constant added to the horizontal velocity at any point as determined for a fixed center, it is perfectly clear that translation along the rail can not affect accelerations in any direction.

No further demonstration is required, but it may be of interest to add a more general solution on geometric lines for the force of inertia developed at any point in a cycloidal path.

Referring to *Fig. 12*, let $P$ be any point in the cycloid $D\,A\,D'$ formed by the point $A$, in the rolling circle $A\,C\,B$ on the base $D\,B\,D'$. $A\,C\,B$ is the axis of the cycloid, and the point $A$ moves to $P$, when the point $B''$ rolls to $B'$. The angle $A'\,C'\,P$ is, therefore, equal to $B\,C\,B''$, and twice the angle $A'\,B'\,P$.

Now, if the describing circle $A\,C\,B$ rolls at a uniform rate it turns through equal angles in equal times, and since the angle $A'\,B'\,P = \theta$ is always half of the angle $B\,C\,B''$, the line $B'\,P$, joining the contact point $B'$ with the describing point $P$, must also be moving with a uniform angular velocity. Using our original notation, where $r_1$ = radius of the

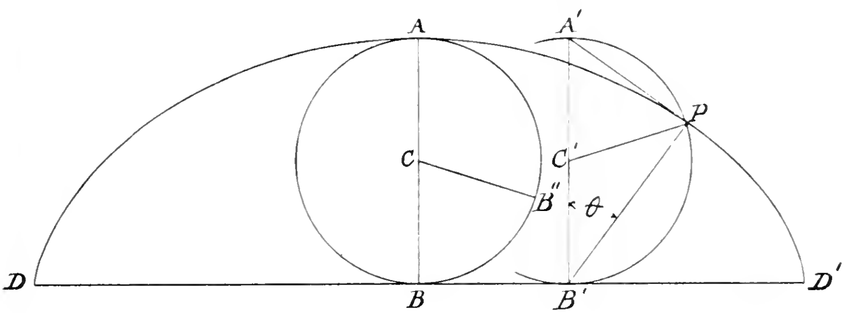



FIG. 12.

rolling circle and $\beta$ its angular velocity, the velocity $v_1$ at the point $A$ becomes $v_1 = 2r_1\,\beta$, and the velocity $v$ at any point $P$ along the cycloidal path is expressed by the equation

$$v = 2r_1\,\beta\,cos.\,\theta \tag{26}$$

Having found $v$, the acceleration $a$ can be determined from the general equation

$$a = \frac{d\,v}{d\,t} \tag{27}$$

Differentiating, equation (26) gives

$d\,v = 2r_1\,\beta\,(-\,sin.\,\theta)\,d\,\theta$, in which we have $d\,\theta = \frac{d\,\beta}{2}$ and substituting this value,

$$d\,v = -\,r_1\,\beta\,d\,\beta\,sin.\,\theta \qquad (28)$$

Obviously $$d\,t = \frac{d\,\beta}{\beta}$$

and we have $$a = \frac{d\,v}{d\,t} = -\,r_1\,\beta^2\,sin.\,\theta \qquad (29)$$

in which the minus sign indicates retardation.

To find the centrifugal force at the point $P$ acting in the direction $B'\,P$, we have the velocity $v$ by equation (26), and the radius of curvature at $P$ being known to be $2\,B_1\;P = 4\,r_1\,cos.\,\theta$, the centrifugal force for a unit of mass is given by substituting these values of $v$ and $R$ in the general formula

$$F = \frac{v^2}{R}, \text{ whence } F = \frac{(2\,r_1\,\beta\,cos.\,\theta)^2}{4\,r_1\,cos.\,\theta} = r_1\,\beta^2\,cos.\,\theta \qquad (30)$$

We now have a mass at $P$ under the impulse of two forces, $a$ and $F$, as expressed by equations (29) and (30). The acceleration $a$ is proportional to the sine of the angle $\theta$, and the centrifugal force $F$ is proportional to the cosine of the same angle. These forces may therefore be represented by the lines $A'\,P$ and $B'\,P$, the resultant of which is a diameter of the rolling circle in the direction $P\,C'$. Or, from equations (29) and (30), we have for the resultant radial force

$$S = \sqrt{a^2 + F^2} = r_1\,\beta^2 \qquad (31)$$

which will be recognized as the general equation for centrifugal force in a unit of mass moving about a fixed center at the radius $r_1$ with the angular velocity $\beta$.

The patents referred to in what has preceded are thus shown to be in contempt of well-established principles, and therefore worthless.

They are as clearly untenable as the idea of perpetual motion, and yet they are the outgrowth of honest enterprise and toil, diligently continued for many years. Technical training in the right direction might have saved the mental energy and material substance so lavishly thrown away. The moral, "A little learning is a dangerous thing," remains as a warning, and as a fruitful result, perhaps some interest may be awakened in a mysterious toy of considerable scientific importance.

# CHEMICAL SECTION.

*Stated Meeting, Tuesday, November 16, 1897.*

## AMMONIA AND ITS SOURCES.

By Dr. Bruno Terne,

Member of the Institute.

Since I had the pleasure of addressing the Chemical Section on this subject, six years have rolled by. Members who were present at the October meeting, 1891, will remember the spirited debate which took place over the probabilities of the ammonia production in connection with the cokeries of the United States.

I take pleasure in referring to the report of that meeting, and it is a still greater satisfaction to me to-night to be able to say to you that the views which I expressed at that time have been verified, and that a beginning has been made by two large companies to produce coke with the gains of the by-products.

While circumstances have prevented my taking active part in the practical development of this industrial branch, in which I had taken a deep interest, I had to leave the field to others more favorably connected. I cannot but feel proud that the views which I expressed six years ago have since been indorsed by reality, and that a new industry has been established in our country.

In my paper I dwelt mainly on the Otto system, of which the patent rights for the United States were purchased by a syndicate about three years ago, with headquarters first in Cleveland, O., and now in Pittsburg, Pa.

The first ovens were constructed in the coke department of the Cambria Iron Company, Johnstown, Pa., and very satisfactory results have been reported. I am not quite sure of the number of Otto ovens in operation in this country; the report in *Mineral Industry* for 1895 puts the number at 60, but I feel sure that this number has now been more

than doubled. I know of 120 Otto ovens being erected in McKeesport, Pa., alone.

In Germany, 2,237 Otto ovens were in operation in 1895, and 480 more of the most improved pattern were built in 1896, in the Ruhr District alone; no more Beehive ovens are being built there, they being replaced with the Otto ovens as they wear out. While in Germany the Otto system is outnumbering all others; Belgium, France and England have also adopted other systems, of which I only name Simon-Carvès, Huessner and Semet-Solvay.

The Semet-Solvay system has taken a firm foothold in the United States; there being in operation to-day 25 ovens at Syracuse, N. Y.; 25 at Sharon, Pa., and 50 at Dunbar, Pa.; in course of erection, 120 ovens at Birmingham, Ala.; 120 at Wheeling, W. Va., and 10 ovens at Halifax, N. S. In reality, the Solvay Company has been the pioneer of this industry in the United States. The first ovens of this kind were, to my best of recollection, built in 1892, and after a year's trial their number has increased to the present figures.

When Prof. George Lunge, in his excellent paper on this subject, published in *Mineral Industry* for 1896, stated that he was informed at the Chicago Exposition (1893) that no coke ovens existed at that time, the report was practically correct, because there were none in the coal regions, and the trials at Syracuse, N. Y., were not generally known. It is worth repeating what this most eminent authority on technical chemistry says:

"The only rational method of coke manufacture is that which utilizes to their full extent the products of the destructive distillation of the coal, instead of wasting them by burning at the mouth of the distilling apparatus, as is done in the antiquated Beehive oven.

"A few words will dispose of the alleged drawbacks of the modern coke ovens, which utilize the heat of their gases.

"The principal objection, tenaciously upheld until quite recently by most of the leading English and American ironmasters, has been that the coke made in new ovens is inferior to the Beehive oven coke, both in respect to crushing strength and fuel value.

"Some of these gentlemen roundly maintained that such coke was simply unfit for use in the blast furnace; others were at least positive that much more of it than of Beehive coke was needed for making pig iron. These views might, at any time, have been refuted by a visit to some Belgian or Rhenish-Prussian iron works; but most of the gentlemen concerned would have scorned to admit that they could learn anything about iron-making from continental people, and would have deemed such visits wholly superfluous.

"Another objection has been made on the difference of cost of erection.

"There are about 45,000 beehive ovens in existence in the United States; their abolition means, of course, the annihilation of a very large capital.

"There is something in the argument, taken from this fact, against the introduction of the new style, but not very much.

"It is simply a matter of calculation whether the interest on the capital required for building new ovens is greater or less than the profits corresponding to the increased yield of coke, and that represented by the value of the by-products.

"The readers of the *Mineral Industry* know well enough that the coke-makers of the United States, until a year ago, have been behind even their British colleagues in this matter.

"When visiting the Chicago Exposition in 1893, I saw, of course, the pretty model of the Connellsville coke ovens in the Mining Building, with the gas flames representing the spectacle offered by the oven mouth on the large scale, and, in the presence of Mr. H. Clay Frick himself, I was asked if I did not admire that exhibit, but I was bold enough to say in that gentleman's presence that I could not bestow any admiration upon the demonstration of an utterly irrational and antiquated method of conducting a technical process.

"I was then informed that not a single coke oven of the novel type was then in existence in the United States, and the same objections were repeated to me which had been

made and refuted over and over again in Europe. To this, of course, I could only shrug my shoulders."

Since then the ban has been broken, and I am satisfied that the step of progress from now on will be a rapid one; the material gain of the new process over the old one will brush away, in a comparatively short time, all prejudice.

Let us pause for a moment, and study the comparative costs between the old and new processes, on the enclosed table, which is taken from *Mineral Industry*, 1895.

The 45,000 beehive ovens have a capacity of 78,750 tons per day, at a cost of $28,350 per day; while the same quantity in the improved Otto oven would cost $10,237 per day, or in the Semet-Solvay system, $4,725.

I can hardly think that, in the face of the fact that the Otto system has gained such universal adoption in Germany, where the strictest economy in all branches of industry is the rule, that it could be so much higher in cost than the Semet-Solvay system; but we have the authority of the General Manager of the Cambria Iron Works, who has stated, as his conclusion respecting the comparative working of different retort ovens, that the Semet-Solvay oven is 30 per cent. quicker in operation than any of its competitors.

Mr. R. M. Atwater, the Secretary of the Semet-Solvay Company, of Syracuse, N. Y., asserts that a single Semet-Solvay oven will produce 2,000 tons of coke from Pocohontas coal, or 1,600 tons from Connellsville coal in one year.

No oven in Europe or America has reported results within 30 per cent. of this record.

To all appearances, at the present time, it seems that the Semet-Solvay oven has taken the lead in economy of operating, by reducing the time of coking.

The 350 Semet-Solvay ovens now in operation are equal to the production of 1,400 tons of coke per day, only $\frac{1}{52}$ part of the capacity of the existing Beehive ovens, but they, in conjunction with the Otto ovens in operation, are the nucleus of a new era in the chemical industry of our land.

We need only to recall how long a time it took to supersede sulphur in the manufacture of sulphuric acid, but how quickly, after the first step had been taken, the pyrites took possession of this industry as a main source.

COMPARATIVE TABLE OF COKE-OVEN COSTS—THEIR OUTPUT AND COST PER TON OF COKE.

| Items. | Kind of Oven. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Not Recovering By-Products. | | | | Recovering By-Products. | | | | | |
| | Beehive. | Belgian. | Bernard. | Coppée. | Otto-Hoffman. | Simon-Carvès. | Huessner. | Semet-Solvay. | Festner-Hoffman. | Siebel. |
| Cost per oven . . . . . . . . . . . . . | $300 | $900 | $1,000 | $1,000 | $4,160 | $2,400 | $2,750 | $3,000 | $3,000 | $2,500 |
| Output of coke per day per oven, net tons . . . . . . . . . . . . . . . . | 1'75 | 2'40 | 2'25 | 2'20 | 3'34 | 2'2 | 2'9 | 4'0 | 2'94 | 3'10 |
| Yield of coke . . . . . . . . . . . . . | 65 p.c. | 68 p.c. | 75 p.c. | 72 p.c. | 75 p.c. | 75 p.c. | 75 p.c. | 75 p.c. | 75 p.c. | 75 p.c. |
| Number of ovens required to produce 100 tons of coke per day . . . . . . | 58 | 42 | 44 | 40 | 30 | 46 | 35 | 25 | 34 | 33 |
| Cost of plant to produce 100 tons of coke per day . . . . . . . . . . . . | $17,400 | $37,800 | $44,000 | $46,000 | $124,800 | $110,400 | $96,250 | $75,000 | $102,000 | $82,500 |
| Repairs and depreciation per ton of coke . . . . . . . . . . . . . . . . | 0'047 | 0'102 | 0'119 | 0'124 | 0'337 | 0'298 | 0'264 | 0'203 | 0'275 | 0'223 |
| Labor on coke and by-products per ton of coke . . . . . . . . . . . . . | 0'320 | 0'270 | 0'250 | 0'270 | 0'390 | 0'390 | 0'390 | 0'390 | 0'390 | 0'390 |
| Total cost per ton of coke . . . . . | 0'367 | 0'372 | 0'369 | 0'394 | 0'727 | 0'688 | 0'654 | 0'593 | 0'665 | 0'613 |
| Value of by-products per ton of coke | — | — | — | — | 0'530 | 0'530 | 0'530 | 0'530 | 0'530 | 0'530 |
| Net cost per ton of coke . . . . . . . | 0'367 | 0'372 | 0'369 | 0'394 | 0'197 | 0'124 | 0'124 | 0'063 | 0'135 | 0'083 |

From the yields of coke from the different ovens shown in above table, it will appear that the beehive requires 1'54 tons of coal to make a ton of coke, while the ovens saving the by-products require 1'33 tons. The value of disposable gas is not included in the figures given, as this will vary greatly according to local conditions, but under any circumstances it should not be less than 20 cents per ton of coke. Adding this value to that of the other by-products, it is safe to say that the cost of coke in the by-product ovens does not exceed the cost of the coal from which it is made.—*Mineral Industry*, Vol. IV, p. 242.

The Pittsburg coal has given an average of from 18 to 22 pounds of ammonia per ton of coal, reckoning it as sulphate.

Taking an average of 20 pounds of sulphate of ammonia per ton of coal, we are still suffering the daily loss of over 2,000 tons sulphate of ammonia by the use of the existing beehive ovens.

Should all the ammonia ever be gained it would not be too much, as the demand for it is constantly growing larger.

A most important step for another source of ammonia has been made by Dr. Ludwig Mond, and brought first to notice in 1889, in his presidential address to the Society of Chemical Industry.

Dr. Mond found that the amount of nitrogen contained in different fuels which he experimented on varied between 1·2 and 1·6 per cent.

When he introduced, together with the superheated air required to burn the fuel in the producer, 2½ tons of steam to every ton of fuel consumed, he found that over 70 per cent. of the total nitrogen in the fuel could be recovered in the form of sulphate of ammonia per ton of fuel from the producer gases. This amounted in practice to nearly 100 pounds of sulphate of ammonia per ton of fuel.

It would take up too much time to go into details of the construction and handling of this gas producer.

Dr. Mond has overcome all adverse criticism of his method by erecting an experimental steel plant in 1895, at the Winnington Works, England, of Messrs. Brunner, Mond & Co. I refer all who are especially interested in this subject to the *Journal of the Iron and Steel Institute*, No. 1, for 1896, in which Mr. John H. Darby published in detail all information desirable.

The Solvay Process Company, of Syracuse, N. Y., has erected a plant of eight Mond producers at its works, replacing the use of coal in the steam plant and elsewhere.

The Semet-Solvay Company controls the Mond process in the United States, and all who are interested in the application of this process will be best served by corresponding with the Secretary of this company Mr. R. M. Atwater.

Fuel gas affords the practical solution of the question of

the smoke nuisance; no factory should be allowed to create such by the use of soft coal. Fuel gas should be delivered to every household of our metropolitan cities, at a price competing favorably with coal.

The production of fuel gas with the gain of ammonia has been demonstrated to be a practical process, which allows the prospect of a return of 25 per cent. on the capital invested.

In the production of ammonia from other sources, I mention the proposition of Sternberg to utilize the sugar-house waste for such purpose by ignition of a mixture of molasses with alkali-aluminate. This process has been patented in the United States under the name of F. O. Matthieson. There are numerous other proposals made, but none have yet brought practical results.

The problem of utilizing the nitrogen of the air as a source for ammonia is still unsolved.

Lord Rayleigh had lately made a study of the oxidation of free nitrogen under the influence of the electrical spark. Siemens & Halske claim that when air, or oxygen and nitrogen, are mixed with ammonia, and subjected to the influence of an electrical discharge, a profitable yield of ammonium-nitrate may be obtained.

It seems, from the results obtained by Lord Rayleigh and Siemens and Halske, that the presence of an alkali to combine with the oxides at the instant of formation is necessary.

Russell and Frank, following the suggestion of Winkler, heated together at red heat, in an open crucible, a mixture of calcium-carbide and magnesium powder, and find that practically all the magnesium is converted to nitride; also, under similar conditions, aluminum, zinc and iron will take up nitrogen.

Mehner, and likewise Willson, exposed such elements as boron, silicon, magnesium, and titanium, which are capable of combining with nitrogen at high temperature, to the heat of the electric furnace, in presence of carbon and nitrogen.

Frank obtained aluminum-nitride by heating the finely-divided metal with powdered calcium-carbide, and declares

that when the metal is heated with dry slaked lime, the nitride may be obtained in large quantities.

Practically, all the nitrides yield ammonia when mixed with water in the cold; the aluminum compound decomposes very slowly. On this ground Frank claims manurial value for it.

The production of nitrides in the electric furnace, by the methods of Mehner and of Willson, may become profitable sources of ammonia.

It will obviously depend on the cost to determine which process will be able to compete with the sources of ammonia which are based on the organic nitrogen compounds provided abundantly by nature.

In close connection with the production of ammonia comes the production of cyanides. This highly interesting and likewise important field lies outside of my subject tonight. I refer you to the review of Prof. Wm. McMurtrie, in the November number of the *Journal of the American Chemical Society*, from which I also quoted the researches to utilize the nitrogen of the air by means of the electrical furnace.

About a year ago we had the pleasure of hearing Prof. H. W. Wiley, of Washington, D. C., tell us of his experiments with bacteria culture to produce nitrogen in the soil.

The firm of Meister, Lucius & Bruning, of Hoechst a-Main, produces cultures of bacteria commercially; the cultures are enclosed in bottles, each containing a sufficient quantity to inoculate half an acre of ground.

These nitrogen-fixing bacteria, when introduced to soils free from them and unsuited to the cultivation of leguminous plants, produce in the roots of such plants nodules, or tubercles, in which fixation of free nitrogen and its conversion into assimilable forms are effected. It is claimed that sterile soil becomes fruitful, and will produce good leguminous crops when inoculated with the bacteria. This new form of agriculture is not over the stage of first experiment; the success of the new enterprise to furnish fertilizer in homœpathic doses remains to be established.

A comparatively new source for ammonia, at present ex-

clusively for the benefit of the farmer, has been created by the utilization of garbage, producing a fertilizer.

At the meeting of the Section, June 20, 1893, I read a paper on the utilization of garbage. At that time the question of disposal of this waste material was hotly debated in our city. The fight was waged over the respective merits of Cremation *vs.* Utilization.

Convinced of the great wrong of destroying this valuable material, I came before your body, and, through the *Journal* of the Institute, before the public at large, called attention to the folly of destroying a material which, if properly handled, is a valuable source for the production of a fertilizer and also of grease.

This paper was well received by the public press, as well as the contemporaries of the *Journal.*

The companies which disposed of the garbage at that time by incineration adopted the method the following year. The same gentlemen who took up the utilization of garbage as a business enterprise were successful in 1896 in securing the contracts for the cities of New York and Brooklyn, and late in 1897 for the city of Boston.

Since September 1, 1896, I have been connected with these companies as chemical manager, and, as such, may be permitted to dwell somewhat more in detail on this new industry, which promises to be an important factor, not onlv in the fertilizer trade, but also in the grease market of the United States.

The processes of utilization may, in the main, be classified as three distinct methods:

(1) The extraction of the greases by hydrocarbons or the naphtha process.

(2) The acid process. Dissolving the crude garbage in sulphuric acid, and after the liberation of the greases, transforming the whole mass at once into a super-phosphate.

(3) The steam-rendering process, commonly known as the Arnold process.

The ideal process, from a theoretical point of view, is certainly the extraction process by naphtha. On account of the prevailing high prices of naphtha, and the unavoid-

able losses of the same, this process has proved to be unprofitable. The first plan of this kind, in Providence, R. I., operating under the Simonin process, is out of existence. The same process in New Orleans, La., has proved to be a financial failure. What system shall take its place has not been decided upon, but a plant operating in Cincinnati, O., is the only one working under these patents.

The cities of Buffalo, Detroit, Milwaukee and St. Louis are working under the Merz naphtha system, but their methods, however, have been so modified that in reality they constitute a steam-rendering system.

The Arnold system is successfully carried on by the American Product Company, of Philadelphia, and the New York Sanitary Utilization Company. Pittsburg is operating under the method of the American Reduction Company—the acid process. Bridgeport, Conn., has a small plant working under the Holtzhous patents, a system apparently well-arranged, but too expensive for practical purposes.

The Philadelphia plant of the American Product Company is situated at the foot of Morris Street and the Schuylkill River. Col. Waring, of New York, in his report on the utilization of waste materials, speaks of the plant as follows:

"Mechanical appliances of the most modern design render manual labor almost unnecessary, and the process is rapid, simple and inexpensive."

The most extensive plant of all is that at the works of the New York Company, situated at Barren Island, in New York Bay. The daily accumulation of garbage of the two cities is varying from 1,000 to 1,500 tons per day, depending upon the season of the year. In the city of New York the gathering is done by the street-cleaning department; in Brooklyn, by contract. In both places the material is loaded on scows, which are towed down to the island. The material is taken by a movable conveyer to the top of the digester room, where it is distributed to the digesters by means of swivel spouts. A digester can be filled with a 9-ton charge in five minutes. The original plant was built to care for the city of New York alone; but since the Brooklyn contracts

have been added the company has duplicated its plant, and will be prepared to handle the increase of material during the summer season with ease.

The great difficulty of handling such vast amounts of material is to apply the most economical methods; the starting of such an enormous work was certainly not without serious trouble. Well planned as the construction of the works has been, it was unavoidable that practical defects should have shown themselves; but step by step the management has made improvements, powerful condensers have been added to care for the escaping gases from the digesters and from the dryers. The liquors from the digesters, which were heretofore allowed to go to waste, are taken care of by a 150,000-gallon triple effect evaporator, built by the Sugar Apparatus Company, of Philadelphia, under the Lillie patents. I have finished, a few weeks ago, the trial test of this apparatus, and after adjusting the same to the peculiar qualities of our liquors, I dare say that we have, in the Lillie apparatus, the very best device to care for our liquors by the utilization of waste steam.

Utilizing the garbage of the two cities, we will add 2,400,000 pounds of ammonia in form of fertilizer, available to the soil, annually to the gain of ammonia.

Adding to the output of our plants the output of other plants, it will be readily acknowledged that by the utilization of city garbage, an enormous quantity of ammonia has been put in circulation, and a benefit to agriculture has been created which has already made itself felt. The fear has been repeatedly expressed that if all the large communities will care for this waste material, the over-production will make the enterprise unprofitable. There is hardly any reason to accept this theory as well founded. In the first place, agriculture demands from year to year more artificial nutrition to the soil; second, the scarcity of stable manure which has been created by the introduction of electrical tramways, doing away with tens of thousands of horses all over the country, makes necessary the replacing of this commodity by some other suitable material, and no manure is better adapted by its physical qualities than the garbage fertilizer to answer this purpose.

# Mining and Metallurgical Section.

*Stated Meeting, May 11, 1898.*

## THE MICROSTRUCTURE OF BEARING METALS.

BY GUILLIAM H. CLAMER,
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Member of the Institute.

The science of microscopic metallography is at present attracting widespread attention, and great developments have of late resulted from this mode of testing. Microscopic examination is fast becoming a factor in testing metals. In the study of iron and steel much work has been done and much information obtained; but the microscopic examination of alloys is a comparatively new piece of research. Chemical analysis can show only the composition of an alloy; but to show the true structure, or manner in which the component parts are alloyed, is left for the microscope. The physical properties of a sound piece of steel depend exclusively upon its chemical composition and upon its structure, and just so with all other alloys; not only should the component parts thereof be known, but also the manner in which these metals are alloyed, as is shown by their structure. We may take, for instance, bearing metals. In these alloys two all-important points requisite to a good bearing alloy, namely, anti-friction and wearing qualities, are greatly dependent upon structure.

It is, of course, first necessary to have the composition correct to meet certain requirements, such as load, speed, etc., and then to have the component parts alloyed in such a manner that the product shall be as fine-grained and homogeneous as possible. The failure of many bearings to give satisfactory service is more often the result of improper mixing than of a poor composition.

It is an undisputed fact that certain combinations of metals are better than others, but it frequently happens that

an alloy of good composition is far inferior to another of poor composition, simply on account of improper manipulation; a good composition in the hands of unskilled foundrymen often yielding a granular and uneven mixture of very inferior quality, while a good metal can be made of inferior scrap by another.

How the wearing qualities are dependent upon structure will be made evident when we consider the definition of wear—"the tearing off of small particles from the worn bodies." Therefore, a bearing metal which is finer in granular structure will wear the slower because of the tearing off of smaller particles.

If a metal is not homogeneous, the anti-frictional qualities will suffer greatly, because of the difference in the hardness and density of the metal in all its parts. The particles of such an alloy form hard spots within the metal, which produce friction.

The homogeneity is greatly dependent upon the treatment the alloy has undergone, and a perfectly even structure can only be obtained by careful and proper treatment.

In view of these considerations, I was led to make a study of the structure as well as the composition of the various bearing metals on the market in this country, and more particularly those which are used in railroad service.

The question as to what is the best metal on which to run our rolling stock is one which is becoming more important every day. We are running our trains on faster schedule; we are increasing the size and weight of locomotives and cars to acquire greater speed, greater carrying capacity and greater comfort.

Only a comparatively few years ago railroad men would have laughed at the idea of attaining the train weights and speeds of to-day. They would have advanced a hundred difficulties in the way of achieving such wonderful results, and chief among these would have been cited the difficulty of obtaining a bearing metal which would meet these requirements. In former times, when speed was not attained and comfort but little considered, a "hot box" was of little consequence; but now the numerous trains are required to

dash along with marvellous regularity, reaching their destination after a run of hundreds of miles on the very minute they are scheduled to arrive. Under these conditions even the slightest delay often leads to the most disastrous consequences. Many accidents are on record which can be traced to a hot box.

Apart from the safety and successful movement of trains which can be accomplished only by the use of well-fitted, well-lubricated bearings, composed of a properly made antifriction alloy, the question of cost is also an important factor—not only first cost, but also the expense which is directly dependent upon the wearing qualities of the alloy and its successful use as scrap. A metal to be successfully used as scrap must have the quality of not deteriorating in remelting. The importance of these considerations is at once obvious to a well-regulated railroad, which considers the great loss occasioned by wear, and the necessity of converting their scrap again into a first-class journal brass.

The alloys now in use for this purpose may be divided into five classes:

(1) White metal alloys.
(2) Miscellaneous alloys.
(3) Copper and tin alloys.
(4) Phosphor-bronze.
(5) Copper, tin and lead alloys.

Cast iron has been tried as a journal metal on railroads, and in fact was used for some years, but I think that it has now been entirely abandoned for the composition metals. Roller bearings have also been experimented with, but, so far as I am aware, have failed to give satisfaction.

The preparation of these alloys for microscopic examination is, of course, of first importance. They must be carefully polished and then etched with a suitable reagent. For copper alloys I prefer to use method of Guillemin, *i. e.*, to attack the specimen electrolytically by exposing it for a few minutes in a bath of very dilute sulphuric acid when connected with a simple Daniel cell, and, in making a comparative study of metals of similar composition, all the conditions must be the same. The method I use is to make a

platinum dish, containing the weak acid solution, the positive pole, and then immerse the specimens to be compared in the solution in contact with the dish, and pass a current through them all at the same time.

The white metal alloys belong to the first class. They are first in anti-frictional qualities, but do not wear well, and furthermore have not sufficient strength to support the great weight of locomotives and cars without distortion or crushing. The practice, therefore, is to use these metals inside of a stronger shell of composition metal.

In car bearings these soft alloys are simply used as a lining, which is not more than $\frac{1}{16}$ to $\frac{1}{8}$ of an inch in thickness. The object of this lining is to give the bearings a good seat without having to be bored out accurately to fit the diameter of each individual axle. The diameters of the axles vary according to the wear they have had, and to fit hard-metal bearings it would be necessary to bore each one to fit each particular axle, and moreover the axles are always more or less rough. The soft white metals easily conform to any such irregularities in the surface of the axle.

This soft composition soon wears away, but by the time this has taken place the bearing has a good seat on the axle, thus doing away with the necessity of fitting each separate journal. The boxes are all bored out to the same diameters and lined with a specified thickness of soft metal. In this way the bearings are all fitted with the minimum expense and confusion. The principal alloy used is one containing antimony and lead; this is sold on the market under the name of "hard lead." It usually contains from 15 to 25 per cent. of antimony, which makes the alloy coarsely crystalline and brittle. It is inexpensive, but gives little wear. Although antimony is a more expensive metal than lead, the "hard lead," or antimonial lead, sells at a lower price than pure lead. The microstructure shows these coarse crystals (*Fig. 1*). With the increase of antimony the crystals are brought into closer contact, indicating the approach to the chemical alloy. Tin greatly improves this alloy. It gives it greater toughness, and makes an alloy which will stand a much greater pressure without distortion, a valuable feature for a babbitt metal.

This is the composition of nearly all the cheap babbitt metals on the market. A good babbitt metal should have as fine a grain as possible in connection with the greatest toughness and hardness obtainable. Tin has the property of greatly reducing the granular texture of antimonial lead. Bismuth in small quantity is added to the lead, antimony and tin alloy by some manufacturers. It is claimed to give greater fluidity and less distortion under pressure. The composition of such an alloy is:

| | |
|---|---|
| Lead | 80·00 |
| Tin | 4·75 |
| Antimony | 15·00 |
| Bismuth | ·25 |

The question of obtaining a fine-grained structure depends greatly on the method of manufacture, temperature of pouring playing an important part, but generally the size of the crystals increase with the increase of antimony, as does hardness; but by proper manipulation a finely crystalline metal can be obtained in an alloy of the following composition, which has a high percentage of antimony, thus making it a valuable babbitt metal:

| | |
|---|---|
| Lead | 70·00 |
| Antimony | 20·00 |
| Tin | 10·00 |

The first white metal successfully used as a bearing metal was invented by Isaac Babbitt. It contained tin, antimony and copper. This metal is used for lining purposes, but can be cast into solid bearings which do not carry too great a load. All white metals used for bearing purposes are now sold under the name of babbitt metal, and when used as a lining the bearing is said to be "babbitted." But to distinguish this metal from the cheaper lead alloys it is sold under the name of "Genuine Babbitt." This alloy is harder than the lead alloys, much tougher, and is finely crystalline and wears well. It is much more expensive, owing to the content of tin. The composition is as follows:

| | |
|---|---|
| Tin | 80·00 |
| Copper | 10·00 |
| Antimony | 10·00 |

Another alloy very successfully used is one composed of:

| | |
|---|---|
| Tin | 68·00 |
| Zinc | 31·50 |
| Copper | 1·00 |
| Lead | ·50 |

It is very tough and bends many times without breaking, due to the peculiar interlocking of the crystals (*Fig. 2*). It has, however, the bad feature of pouring sluggishly. I have no knowledge of the wearing qualities of this metal.

I will next consider the miscellaneous alloys. Under this head may be included any alloy, it matters not what the composition, so long as it produces a reasonably good casting. It includes all alloys having over 60 per cent. of copper and the remainder made up indiscriminately of zinc, tin, lead, antimony and any other metals which happen to be in the scrap pile.

Such compositions as these are used on freight cars, and, indeed, by some roads in passenger service, their only aim being to get a cheap composition. No attention is paid to wearing or other qualities, and the running expense is not taken into account; it is only first cost. If a bearing gets hot or wears out, it is removed and thrown into the scrap pile, to be again remelted. Foundrymen receiving this scrap term it all "red brass," and without any knowledge of the composition, again convert it into journal bearings.

The scrap pile always contains more or less zinc, and indeed anything from yellow brass up is considered good enough for a cheap bearing metal,

*Fig. 3* shows the structure of yellow brass of:

| | |
|---|---|
| Copper | 66⅔ parts |
| Zinc | 33⅓ " |

It is beautifully crystalline and the size of the crystals varies greatly with the method of treatment. Zinc has the property of giving greater solidity to alloys of copper, tin and lead, 1 to 2 per cent. being sufficient for this purpose, and when more than this is used in connection with other scrap the effect is more or less injurious. If the scrap metal coming from the railroads was first melted and run into pigs

and analyzed, uniform results could be obtained by building up the scrap with new metal to the desired composition; but the present low price of such material would not warrant this extra expense; and, indeed, I have known of such bearings to be cast, bored out and lead-lined for $7\frac{1}{2}$ cents per pound. But even so, with proper care, a fairly good metal can be made from such scrap.

*Fig. 4* shows a bearing metal made of scrap which has been carefully treated; it contains a high percentage of lead, but shows no liquation of the lead as would be expected in an alloy of this nature.

*Fig. 5* shows a copper and tin alloy, containing a little lead, in which manganese has been used as a deoxidizer.

The alloy of copper and tin some years past was considered the standard bearing metal on railroads, but is now little used. These metals alloy to form a very hard and crystalline alloy, *Fig. 6*, the usual proportion being that of cannon bronze—7 parts of copper to 1 part of tin. Although this alloy is much harder than the standard metals of to-day, yet it is found to wear much more rapidly and produce more friction. Dr. Dudley, chemist to the Pennsylvania Railroad, some years ago gave the results of a long series of experiments before the Franklin Institute, in which he compared the copper and tin alloy with standard phosphor-bronze, which contains lead. He found that the copper and tin alloy was much more liable to heat under the same state of lubrication than the standard phosphor-bronze, and second, that the rate of wear with the copper and tin alloy was nearly 50 per cent. greater than that of the standard phosphor-bronze. And still, in spite of these facts, some railroads still go on in the old way specifying copper and tin, a more expensive alloy than the phosphor-bronze, or the copper, tin and lead composition.

These experiments led directly to the use of standard phosphor-bronze bearing metal on the Pennsylvania Railroad, and indirectly to its use on other large roads. Thus, by practical experimentation and experience, railroad men to-day recognize but two alloys as standard: (1) Copper, tin and lead alloy, containing phosphorus, known as phosphor-

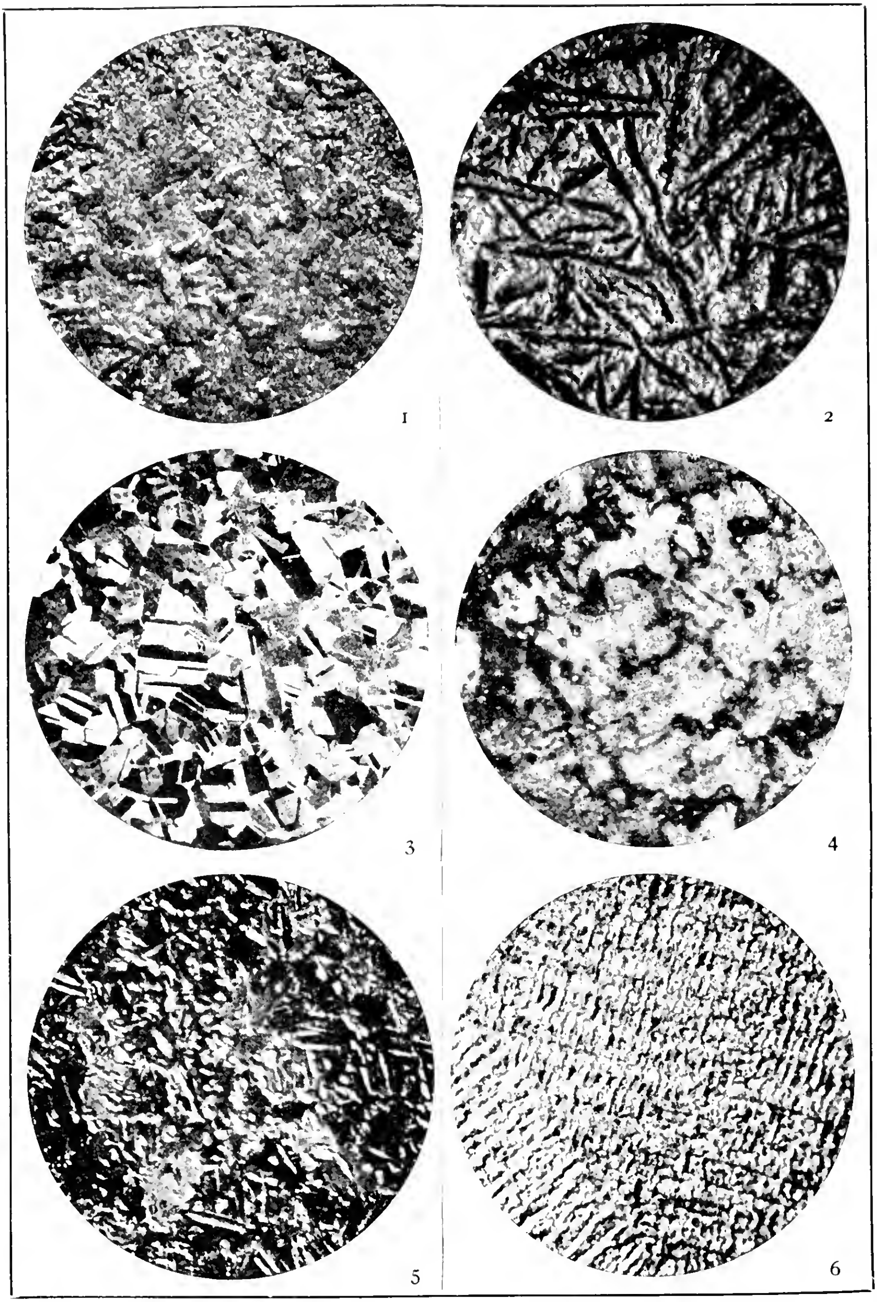
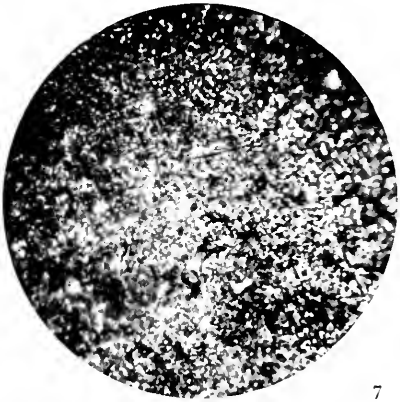



FIG. 1.—Antimonial lead.
FIG. 2.—Tin and zinc with little copper and lead.
FIG. 3.—Copper and zinc.
FIG. 4.—Copper, zinc, tin, lead, iron.
FIG. 5.—Copper and zinc with little lead (manganese used as deoxidizer).
FIG. 6.—Copper and tin.



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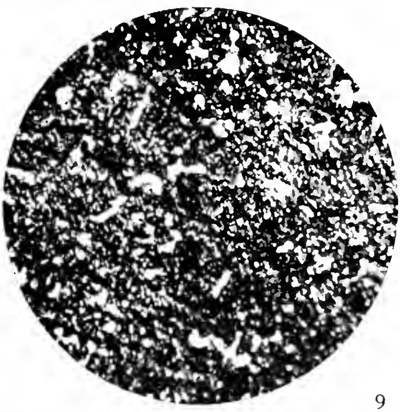

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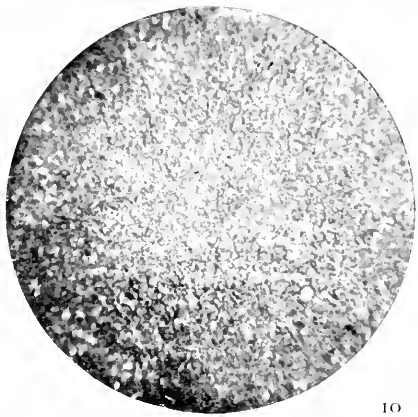

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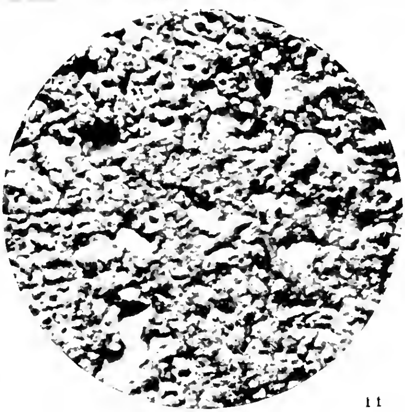

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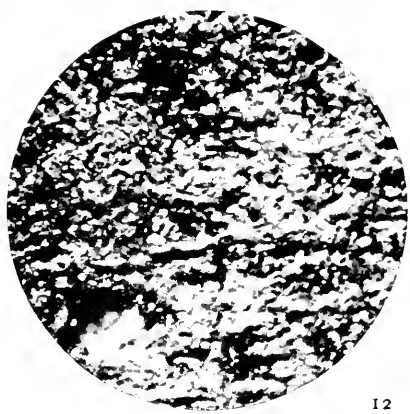

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FIG. 7.—Copper, tin, lead and phosphorus (1st melting).

FIG. 8.—Copper, tin, lead and phosphorus (after repeated meltings).

FIG. 9.—Copper, tin and lead (1st melting).

FIG. 10—Copper, tin and lead (after repeated meltings).

FIG. 11.—Copper, tin and lead, showing liquation of lead.

FIG. 12.—Copper, tin and lead, showing liquation of lead.

bronze. (2) Copper, tin and lead. I do not say that either of these alloys is the best that can be devised, but up to the present time, and with our present knowledge, they are the best compositions for car and locomotive journal bearings. As far as wearing is concerned, I do not think the phosphorus introduces any advantage, and, as Dr. Dudley says, he has no evidence to show that the phosphorus has any other use except to produce sound castings.

I had occasion very recently to find, by a practical test, that the alloy of copper, tin and lead gave better results, so far as anti-frictional qualities are concerned, than the alloy containing phosphorus. That the bearings without phosphorus showed a much less tendency to heat than the phosphor-bronze was clearly demonstrated. The test was made by placing the phosphor-bronze on one side of the axle and the simple alloy on the other. The tests were strictly comparative in every way, and the number of hot boxes of the phosphor-bronze metal greatly exceeded the simple alloy. And it has been found, by practical experience, that remelted phosphor-bronze is much more liable to heat than the newly-made metal.

In order to discover why the remelted scrap phosphor-bronze should be inferior to the newly-made material, I determined to make some experiments in a practical way. The fact that the phosphor-bronze scrap is far inferior to new metal is well known, and I believe the general impression has been that the inferiority was due to the burning out of the phosphorus, as it is for this reason that the specifications of standard phosphor-bronze call for a high percentage of phosphorus, in order to make provision for loss in remelting, and with the idea that the remelted scrap will still retain sufficient phosphorus not to deteriorate its qualities. By my experiments I find this to be an entirely mistaken idea, because, in the first place, phosphorus only burns off in very small proportions, when once thoroughly contained in the alloy; and secondly, that the inferiority of the metal is directly due to the high percentage of phosphorus, for the reason that it combines with the tin and copper to form hard crystalline phosphides, which are, to a

great extent, dissolved in the alloy when the metal is new, but separate or crystallize out in the old material.

Six hundred pounds of phosphor-bronze was made of good selected material, and every precaution used in manipulating. It was then poured into ingots and borings taken from the first, middle and last ingots, and the borings mixed and analyzed. The analysis showed:

| | |
|---|---|
| Copper | 78·72 |
| Lead | 9·89 |
| Tin | 10·58 |
| Phosphorus | 1·04 |

Three hundred pounds of these ingots was now weighed off and remelted, and again poured into ingots and weighed, and the loss carefully noted; the metal being melted and poured in this way ten times, and the loss noted in each heat with the following results:

| | *Pounds.* | | *Pounds.* |
|---|---|---|---|
| 1st | 3·5 | 6th | 2 |
| 2d | 3·0 | 7th | 3 |
| 3d | 3·0 | 8th | 3 |
| 4th | 2·5 | 9th | 4 |
| 5th | 3.5 | 10th | 7 |

The total loss was 34·5 pounds, or 11·5 per cent. on ten heats, and the average loss per heat 1·5 per cent. It will also be seen how uniform was the loss on every heat; the last heat only showing considerable deviation, which I attribute to the metal being insufficiently hot to flow cleanly from the crucible.

Borings were taken from the first, middle and last ingots of the tenth heat, well mixed and analyzed. The metal now contained its constituents in the following proportions:

| | |
|---|---|
| Copper | 80·39 |
| Tin | 10·40 |
| Lead | 8·35 |
| Phosphorus | ·87 |

The analysis shows that very little phosphorus has gone off, despite the fact that the metal was melted and poured ten times, the lead showing the greatest loss. The following table will show the loss in weight very closely, as shown by the analysis:

| | *1st Heat.* | *10th Heat.* | *Loss in Pounds.* |
|---|---|---|---|
| Copper | 235·47 | 213·41 | 22·06 |
| Tin | 29·67 | 27·61 | 2·06 |
| Lead | 31·74 | 22·17 | 9·57 |
| Phosphorus | 3·12 | 2·31 | ·81 |

These results show that the phosphorus is held in bronze in the form of phosphides, which high temperature can drive out only in very small proportions. The metal under the microscope was now decidedly crystalline. These crystals are intermixed or held dissolved in the new metal, but when subjected to remelting become organized and crystallize out in the alloy, thus greatly reducing the anti-frictional and wearing qualities of the metal. The resulting metal after the tenth heat was so hard it could scarcely be touched with a file. { *Fig. 7.*—New phosphor-bronze.
*Fig. 8.*—Remelted phosphor-bronze.

A copper, tin and lead alloy of the same composition was treated in the same way; the loss on this metal was 34 pounds, being within half a pound of the phosphor-bronze, and the loss on each heat was as follows:

| | *Pounds.* | | *Pounds.* |
|---|---|---|---|
| 1st | 7 | 6th | 4 |
| 2d | 3 | 7th | 2 |
| 3d | 1 | 8th | 3 |
| 4th | 4 | 9th | 3 |
| 5th | 4 | 10th | 3 |

This metal became harder and closer-grained after the repeated meltings, but showed no signs of becoming crystalline or granular.

*Fig. 9.*—New copper, tin and lead alloy.

*Fig. 10.*—Remelted copper, tin and lead alloy, made by the Ajax Metal Company's process, which insures the homogeneous distribution of the lead.

Many alloys of copper, tin and lead are manufactured by foundrymen under the name of anti-frictional metal and are sold under various well-sounding names, which are supposed to indicate their qualities.

To one who is unacquainted with or does not consider the chemical and physical properties of lead, it appears an easy matter to make such an alloy by merely melting in a

crucible the three metals in the stipulated proportions; but when we consider the greater density, the lower melting point, and the slight affinity of lead for the copper and tin alloy, a more serious question results. I have found, by my repeated microscopic examinations of many such alloys of different makers, that lead is in no instance combined or really alloyed with the copper and tin, or perhaps only in small proportions, probably not over one per cent.; the remaining lead being held diffused through the alloy in its combined state, or with small proportion of the tin and copper, but not enough to destroy the grayish-blue color.

Such an alloy under the microscope is seen to be made up of two principal colors, the bronze-colored combined copper and tin, and the grayish-blue lead. Now, this being the case, it will be seen how difficult and also important it is to obtain an alloy which will show the same structure and percentage of lead in all its parts. The difficulty in obtaining such an alloy is this, as I have stated:

(1) The lead is not combined with copper and tin.

(2) Owing to the high specific gravity and the lower melting point of the lead, its tendency is to go to that part of the casting which has last solidified, or to distribute itself unevenly throughout the mass.

I will now show the structure of copper, tin and lead alloys of several makers; they all have about the same composition and were all cast in the same size bars, great care being taken to have the conditions as nearly alike as possible. A section was cut out of the middle of each bar for examination.

*Fig. 11* shows the structure of an alloy of the following composition:

| | |
|---|---|
| Copper | 76·88 |
| Tin | 10·62 |
| Lead | 11·71 |

It shows that the lead has liquated, leaving an unsound metal. The dark spots are holes and the lighter particles lead. That such a segregation of the lead greatly reduces the value of a composition of this nature is very evident.

*Fig. 12.*—A metal of following composition:

| | |
|---|---|
| Copper | 76·66 |
| Tin | 11·68 |
| Lead | 10·83 |

This shows a still greater segregation of lead. In this metal the lead is very unevenly distributed, it having formed large pools through the alloy.

Of all metals, lead is by far the first in anti-friction qualities; and if to the strength of copper and tin there is added a suitable proportion of lead, thoroughly and evenly distributed throughout the mass, the bearings as they wear are constantly in contact with soft anti-friction particles of lead, which are backed by the harder particles of copper and tin. If in such an alloy the lead is not homogeneously distributed and without liquation, both the wearing and anti-frictional qualities are greatly affected.

After going through the whole subject of the composition of metals suitable for bearings, the thoroughly homogeneous alloy of the proper proportions of copper, tin and lead seems to me to be the best suited for the purpose, and this has also been demonstrated in actual service by the use of such an alloy on all the record-breaking trains of recent years, notably the New York Central & Hudson River Flyer from Albany to Buffalo, which made the run of 436½ miles in 407 minutes, with the bearings perfectly cool throughout the entire run; and on the fleetest ocean greyhounds that cross the ocean.

The alloy of copper, tin and lead, of proper composition and homogeneous structure, I think I am safe in saying, has greater anti-frictional qualities than any other composition of sufficient strength to be used as a journal brass in railroad service. This fact has been demonstrated several times by actual practical tests, and furthermore, it does not deteriorate in remelting.

As structure is of such importance in a bearing metal, I think the micro-test should be included in all specifications as equal, if not greater in importance than chemical analysis.

DISCUSSION.

MR. JAMES DE BENNEVILLE.—Mr. Clamer's paper with the microsections he has exhibited throws additional and

valuable light on the structure of alloys which recent investigation is beginning to connect so closely with the action of solvents and dissolved substances. To refer more particularly to iron carbides, the microstructure of these bearing metals and of steel can be read together in the same light only up to a certain point. In comparing the two, the structure of the eutectic is an important determination. These mixtures have been shown, by the interesting work of Mr. Charpy, to possess a laminar structure, and are described by him as of the same nature as cryohydrates, the heterogeneity of which has been thoroughly established by Offer. Granted such heterogeneity, presence or absence of structure has a most important bearing on the structure of steel and kindred iron carbides. Mr. Charpy has pointed out that in the pearlyte structure of annealed steel all the conditions of a eutectic are found. Now, if we turn to the much-discussed ·90 carbon steel quenched above $Ar_3$ (martensite), this is not found to be the case. Micrographists are substantially agreed that no structure can be detected in such steel. It is homogeneous. Two explanations have been put forward to explain this case: (1) that the carbon is dissolved in the iron and all compounds have disappeared, the relation of carbon to iron being analogous to that of sugar in water; and (2) that a definite compound of iron and carbon has been formed, viz.: $Fe_{24}C$. Difficulties arise in applying either of these explanations. If at high temperatures carbon is simply dissolved in iron, and is so retained on rapid cooling, thus forming a solid solution, the chemical relation known to exist between iron and carbon, and giving rise to cementite ($Fe_3C$) must be put aside, but it is to be noted that although carbon can be dissolved by iron, only carbide of iron can be again separated on slow cooling, unless a certain percentage of carbon is exceeded. If, however, the presence of cementite is admitted, the unusual example is presented of complete dissociation of the compound $Fe_3C$ in somewhat concentrated solution, whereas it has been found that in the case of electrolytes the more advanced the dissociation the greater is the dilution required. For

carbon, martensite covers the range up to ·90 per cent. In quenched low carbon steel of ·20 carbon, microanalysis shows two constituents, ferrite and martensite. If martensite is a definite compound, the explanation $Fe_{24}C$ is accepted. If it is structureless in ·90 carbon quenched steel, there is surely no reason to assume structure in ·14 carbon quenched steel. To reject definite composition is to grant that martensite of ·90 carbon steel is not identical with martensite of ·14 carbon steel. If martensite varies in composition with the composition of the steel in which it is found, one distinguishing feature of a eutectic is at once lost, viz.: constancy in its physical properties; for this very constancy first gave rise to the idea that these mixtures, having constant boiling points, freezing points, etc., were definite chemical compounds. It is the definition of a eutectic.

As cast iron and vitreous silicates showed analogies in their conduct toward reagents, the writer (1894) was led to associate these "mother liquors" of iron carbides with such vitreous silicates. If martensite is regarded as analogous to such a compound, many difficulties are removed, and its varying composition, ultimate and proximate, can be understood. Can the indefinite structure of the vitreous silicates be regarded as necessarily implying a solution holding ions of calcium, magnesium, silicon and other elements? The definite ratios found to exist in the silicates, and which allows their range and the replacing value of each element to be predicted, does not uphold this view. The vitreous silicates can indeed be regarded as a solvent for certain compounds (feldspar, etc.), in the sense that water is a solvent. It does not imply anything more. Moreover, it is to be remembered that solution does not necessarily imply ionization, of which instances can be cited in the small value of $\mu$ for complex organic acids, and also when solvents other than water are used. The homogeneity of ·90 carbon steel, hardened by quenching from 1,000°—martensite—presents peculiarities not yet detected in the structure of the alloys described by Mr. Clamer and others.

THE PRESIDENT OF THE SECTION.—The phenomenon known as "segregation" of alloys, which has been alluded to

by Mr. Clamer in his interesting paper on the microstructure of bearing metals, is a remarkable one, apparently forming an exception to ordinary chemical laws.

It is an important subject for investigation by metallurgists and chemists, and if the microscope can cast new light upon the strange behavior of such alloys it will add much to the practical utility of this instrument in the laboratory.

Segregation is often used as a convenient cloak to cover faults of melting; but apart from this, it is indeed a serious trouble to the melter who aims to obtain homogeneous alloys.

The most thorough investigation of segregation with which I am familiar was made in the assay department of the mint, a good many years ago, with various alloys of the precious metals used in coinage. It was proved that when gold and copper were melted together in the proportion required for the American coin, *i. e.*, 900 parts of gold and 100 parts of copper, and the molten metal poured into ingots, after having been thoroughly rabbled with a plumbago stirrer, a homogeneous alloy resulted; test pieces cut from different ingots all assayed alike, within a minute fraction—not more than one or two ten-thousandths variation above or below the standard. When, however, an alloy of 900 parts of silver and 100 parts of copper was poured into ingots, after having been thoroughly mixed, considerable irregularity was found to exist in the distribution of silver in different ingots, and even in different parts of one ingot, and this variation was proved to be solely owing to segregation into richer and poorer alloys; furthermore, it was discovered that there was a specific alloy of silver and copper of certain proportions—I believe about 750 parts of silver and 250 parts of copper—in which segregation was almost *nil*.

In some of the silver-copper alloys the silver segregates towards the center of the mass, leaving copper in excess near the exterior portion. In other similar alloys a reverse effect was observed, and this is, of course, independent of the specific gravity of the metals.

The coinage silver laws of the United States permit a

comparatively large variation (called the "legal tolerance"), from the standard equivalent to $\frac{3}{1000}$ above or below 900 fine, on this account; but segregation may actually cause a variation in the fineness of two silver dollars struck from one ingot, or even in the metal clipped from different parts of a single dollar, sufficient to condemn the coin if judged from these assays alone; in order, therefore, to obtain an average sample of a melt of standard silver-alloy for coin, it is the universal practice in minting operations to dip out from the melting pot (containing usually 3,000 ounces of fluid metal) a small sample immediately after thorough stirring, and to quickly pour it into cold water; the alloy is thus instantly congealed into the form of shot or "granulations" and segregation does not occur under these conditions. Assays are then made of these granulations, and duplicate analyses must agree within very small limits of permissible variation.

About twenty years ago I made some few investigations with the microscope of silver-copper alloys with the view of trying to ascertain the cause of segregation, but met with little encouragement, and I am interested, therefore, to know whether Mr. Clamer has succeeded in solving this riddle through his more thorough study of the microstructure of bearing metal alloys.

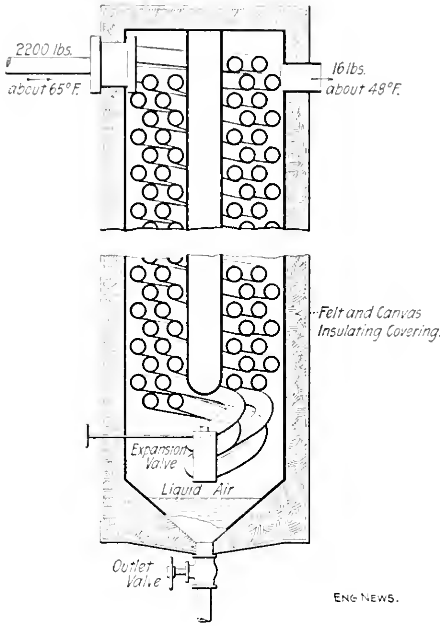
## NOTES AND COMMENTS.

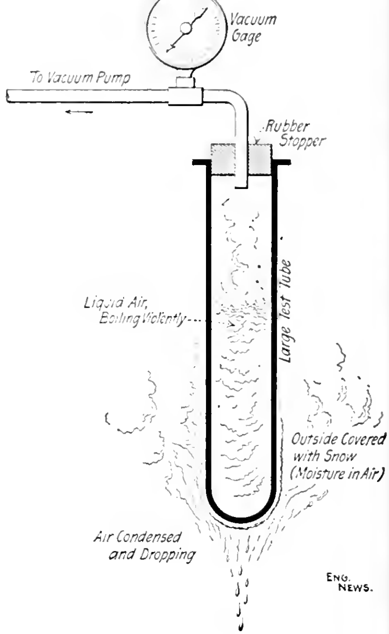
### TRIPLER'S APPARATUS FOR THE COMMERCIAL MANUFACTURE OF LIQUID AIR.

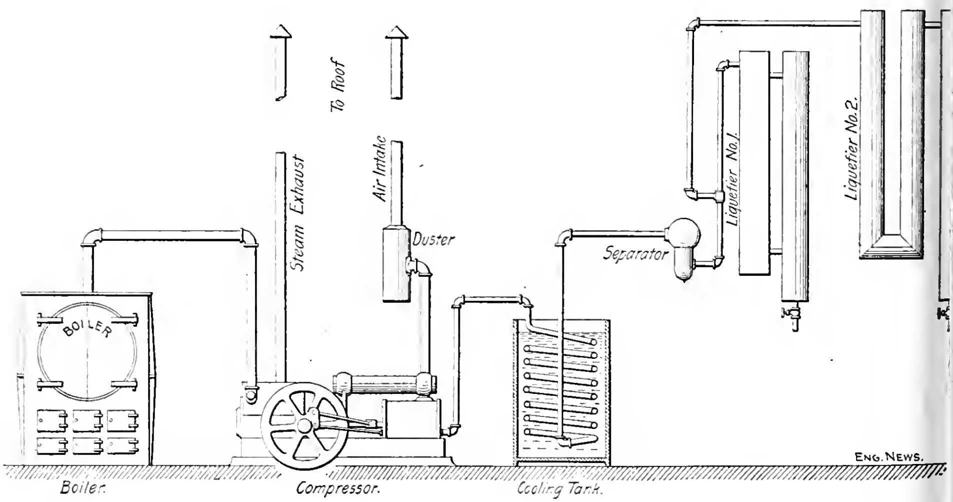
*Engineering News* of recent date contains the first intelligible account that has yet appeared concerning the construction and operation of the apparatus by which Mr. Chas. E. Tripler, of New York, has succeeded in successfully solving the problem of producing liquid air as an article of commerce. The following description is gleaned substantially from that which is published in the *News*, and which purports to be based on actual observation by a member of its staff:

From this account it appears that the apparatus, aside from a special portion of the mechanism, called by the inventor a "liquefier," is an ordinary compressed air plant.

The power is obtained from a steam boiler which supplies steam at about 85 pounds pressure to a Norwalk straight-line compressor rated at 90 horse-


2200 lbs.
about 65° F.
16 lbs.
about 48° F.
Felt and Canvas Insulating Covering.
Expansion Valve
Liquid Air
Outlet Valve
Eng News.


Vacuum Gage
To Vacuum Pump
Rubber Stopper
Large Test Tube
Liquid Air, Boiling Violently
Outside Covered with Snow (Moisture in Air)
Air Condensed and Dropping
Eng. News.


To Roof
Steam Exhaust
Air Intake
Duster
Separator
Liquefier No. 1.
Liquefier No. 2.
Boiler
Boiler.
Compressor.
Cooling Tank.
Eng. News.

power when running at 150 revolutions per minute. The steam cylinder is 16 x 16 inches. There are three air cylinders arranged in tandem with the pistons all on the same rod. The low-pressure cylinder ($10\frac{1}{2}$ inches in diameter) is double-acting, and raises the pressure from that of the atmosphere to between 55 and 65 pounds. The intermediate is single-acting ($6\frac{7}{8}$ inches in diameter), and compresses to between 350 and 400 pounds. The high-pressure cylinder ($2\frac{5}{8}$ inches in diameter) is single-acting, and delivers the air at a pressure of from 2,000 to 2,500 pounds per square inch.

The compressor takes its air supply through a dust separator placed in the roof, thus insuring the admission of clean air. This separator is an arrangement of baffle-plates over which water is constantly trickling. From the high-pressure cylinder the air passes to a cooling tank—a spiral coil of copper pipe surrounded by a stream of running water. The purpose of this device is to carry off the heat stored in the air during its compression. The air passes on then at the temperature of the cooling water. From the cooling coil the air next passes through a "separator," or dryer, the function of which is to remove the moisture contained in it originally and that which it may have taken up in the dust separator and elsewhere.

The next piece of apparatus is what the inventor calls a "liquefier," the function of which is to transform the now cool air—which is at a pressure of about 2,200 pounds to the square inch—into liquid air at atmospheric pressure and at a temperature 312° F. below zero. In this portion of the Tripler apparatus, therefore, the actual work of liquefaction is performed. There are two of these liquefiers in use in the laboratory apparatus here described. Their operation is substantially as follows:

The comparatively cool air under high pressure enters at one end of the liquefier, where it passes through an arrangement of coils of pipes towards the other end, where there is situated an expansion valve of peculiar construction which permits a certain amount of air to escape into the surrounding casing. This expanding air flows in a direction opposite to that of the entering air, and, in flowing in and about the coils, it absorbs heat from the incoming air, greatly reducing its temperature. This accumulative chilling action of the expanding portion of the air continues to reduce the temperature of that contained in the coils more and more, until at length its "critical temperature" (placed by Dewar at 220° F. below zero) is reached and a portion of the air collects at the bottom of the liquefier in the liquid form, while the remainder flows on, expanding and continuing to exert its chilling effect on other portions of entering air. Externally, these liquefiers resemble sections of covered steam pipe, and give no intimation as to the duty they perform. The liquid air is removed from the liquefier by opening a valve in the bottom.

The laboratory apparatus above described is capab'e of producing from 3 to 4 gallons of liquid air per hour continuously.

[The *Journal* is indebted to *Engineering News* for the use of the accompanying illustrations.] W.

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## JAPANESE PATENT LAW.

In the treaty entered into March 11, 1897, between Japan and the United States of America, were provisions for the protection by patents in either

country of the inventions of citizens of the other. The Japanese patents are granted for any one of three terms, namely, five, ten or fifteen years, reckoned from the date of registration, these terms not being alterable after the patent has been granted. Designers of improvements on patented inventions are required to obtain a license from the patentee of the original invention before applying for a patent upon the improvement. If this license to use the original invention cannot be obtained, the Minister of State may grant the patent, fixing the compensation to be paid to the original patentee. No annuities are required, but patents shall be forfeited when the patentee, without sufficient reason, has not exploited his invention within three years of the date of his patent, or discontinues working the invention for three years at any time, or when the patentee imports and sells an article for which he has obtained a patent, or acquiesces in the selling of an article which infringes his rights. Infringers of patent rights are liable for damages to the patentee, the term of liability being three years.—*Electrical World.*

## THE CARBON DIOXIDE MOTOR.

At the stated meeting of the Franklin Institute held April 20th, Mr. Wm. F. Roberts described and exhibited in operation an engine devised by him, which is actuated by carbon dioxide.

The engine exhibited was a triple cylinder machine, 2-inch bore and 2-inch stroke, double acting. It was shown in both vertical and horizontal types. In the horizontal engine the bed-plate is 24 x 14 inches; and in the vertical form 14 x 10 inches; height, 18 inches. The power is transmitted from both ends of crank-shaft.

The cylinders are fitted with positive, automatic cut-off valves, operated by a cam mechanism and cutting off at one sixty-fourth of an inch. The claim is made that the engine is capable of running at 2,000 revolutions per minute under a pressure of 1,500 pounds per square inch, and of developing under those conditions twenty-five horse-power. The total weight of this horizontal form of engine, including bed-plate, is eighty-five pounds.

The engine is supplied with gas from steel cylinders containing the carbon dioxide in the liquefied state, communication with the cylinders being established through a small copper pipe coiled in the form of a helix. In this helix the gas is heated until the desired pressure is obtained. A very large return is claimed. W.

## THE ALUMINUM INDUSTRY.

From London *Engineering* we learn that the present output of aluminum in the world is a little less than 10 tons a day, of which about one-fifth is produced in the United States. In Great Britain, the British Aluminum Company has its works, at the Falls of Foyers, in full operation, using about 3,500 horse-power for the production of calcium carbide and aluminum, and making about 6,000 pounds of the latter a day. This company is making preparations for a very much larger output. In France the Société Electro-Metallurgique Française, at Le Praz, makes 3,600 pounds a day with 3,000 horse-power by the Heroult process, and the Société Industrielle d'Aluminium at St. Michel

makes 5,000 pounds with 4,000 horse-power by the Hall process. In Switzerland the Aluminum Industrie Aktien Gesellschaft, at Neuhausen, makes 5,000 pounds a day with 4,000 horse-power by the Heroult process. The demand for aluminum in the United States has lately been largely increased by purchases for Japan, and it is not unlikely that Europe will shortly be subjected to an inundation of Japanese art work in this metal.

The seven works at present producing aluminum are using either the Hall or the Heroult process. There have recently been hints in one of the papers devoted to the interests of this metal of a possible combination of the various producing firms for regulation of the output and the price. The current price quoted for the best grade aluminum in England is 33·2 cents per pound. A recently published estimate of the cost of production by Roberts-Austen was 27·2 cents per pound, of which only 2·2 cents is for electrical energy, while 12 cents is for the raw material of the manufacture. Becker, the former manager of the aluminum works at St. Michel, has published in his paper, *L'Industrie Electro-chimique*, a method of reducing this latter item by substitution of calcined bauxite, at 1 cent a pound, for the refined alumina generally used. Since 2·2 pounds of this calcined bauxite would suffice to produce 1 pound of the metal, it follows that such a substitution would reduce the cost of aluminum by 9·8 cents per pound. The aluminum produced, however, would contain about 6 per cent. silicon and iron as impurities; and in order to obtain from it high-grade aluminum, Becker would refine it by a wet process with which he is at present experimenting.

Minet's process for the production of aluminum, which was worked at St. Michel by Messrs. Bernard Brothers, of Paris, from 1890 to 1894, when it was displaced by Hall's process, has recently been further experimented with at St. Michel. The process consists in the electrolysis of a fused mixture of aluminum fluoride and common salt, and it is said that a pressure of only 3 volts is required to effect the separation of the aluminum from this electrolyte.

Blackmore, of New York, has suggested the use of aluminum sulphide, manufactured by a cheapened method, in place of the oxide. Kershaw has examined this proposal, and shown that it would not effect any reduction in the cost of the metal. Blackmore has also described a metallurgical method for producing aluminum which is more promising. Molten iron in shot form is allowed to descend through aluminum sulphide dissolved in molten fluorides of the alkali metals; the aluminum sulphide is robbed of its sulphur by the iron, and molten aluminum collects at the bottom of the vessel. Blackmore states that this process has been tried on an experimental scale with satisfactory results; but no details of the purity of the aluminum obtained by it have yet been published.

The influence of small amounts of carbon upon the physical properties of iron is so remarkable that it is interesting to note that repeated attempts have been made to obtain aluminum with a small percentage of it as carbide. The difficulty has been to get the carbide formed at temperatures below that of the electric arc. Dr. Roman has, however, patented a method for effecting the combination indirectly by means of calcium carbide. The aluminum and calcium carbide are melted together in the required proportions, and in this way the carbon is transferred to the aluminum at a comparatively low temper-

ature. Aluminum containing from 0·1 per cent. to 1·5 per cent. carbon has been produced by this method, and this is said to possess great elasticity and hardness. Dr. Roman has also patented an alloy of aluminum containing 1 per cent. nickel and 1 per cent. wolfram, which possesses the color of pure aluminum, but has much greater tensile strength and takes a finer polish.

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## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held June 1, 1898.*]

PROF. L. F. RONDINELLA in the chair.

The following reports were adopted:

*Hard-drawn Copper Wire.*—Thomas B. Doolittle, Branford, Conn.

ABSTRACT.—The report refers to the fact that Mr. Doolittle, in the year 1877, suggested the use of hard-drawn copper wire for telephone and telegraph uses, and in the same year, at the works of the Ansonia Brass and Copper Company, Ansonia, Conn., succeeded, after many experiments, in producing about 500 pounds of this material, which was employed on a telephone line connecting these works.

This method consists in using drawing-plates containing a larger number of holes than the ordinary plates used in copper wire drawing, and increasing the number of passes for a given reduction of area. By this means it is possible to draw copper wire from the beginning to the end of the operation without any annealing, and at the same time to avoid the crystallizing of the metal. The wire thus produced is sufficiently flexible to permit of the formation of standard telegraph wire joints without breaking or cracking.

The hard-drawn copper wire made by the Doolittle method has its tensile strength doubled and its elongation reduced to about 1 per cent., while its electrical conductivity is not materially impaired.

The report dwells upon the great utility of such hard-drawn copper wire for aërial conductors on account of its high conductivity and great tensile strength and reliability in prolonged service, which were amply demonstrated by Mr. Doolittle in his efforts to secure its adoption by the electric line builders; and it was due entirely to his persistent endeavors that hard-drawn copper wire was, at length, adopted for telegraph and long-distance telephone purposes.

Hard-drawn copper wire has now become a staple article of manufacture, not less than 8,000,000 pounds having been produced in the United States alone, in 1896. It is now frequently employed for all kinds of electric conductors, and especially for long-distance telephone lines, the successful operation of which, the committee of investigation admits, is in large measure due to its introduction.

The report concludes that Mr. Doolittle is entitled to recognition:

(1) For having been the first to recognize the value of hard-drawn copper wire; and for having, by his persistent endeavors, in the face of adverse conditions, succeeded in establishing its use for electric conducting wires; and

(2) For his long-continued experiments and labor in overcoming the many

difficulties encountered in producing, on the commercial scale, a hard-drawn copper wire suitable for electric conducting wires.

The Edward Longstreth Medal of Merit is awarded to Mr. Doolittle. [*Sub-Committee.*—Charles James, Chairman; D. Anson Partridge, Tinius Olsen, Clayton W. Pike.]

*Expert Testimony.*—[Investigation ordered by the committee.]

ABSTRACT.—Under-mentioned sub-committee was instructed to investigate and report upon the question of the propriety of sub-committees accepting outside expert evidence, and the extent to which such evidence may be accepted by sub-committees in reaching their conclusions.

The opinion is expressed in the report that the question of accepting expert testimony must, in each case, be left to the discretion of the investigating committee, subject, of course, to the revision of the general committee. It is suggested that any sub-committee basing its report upon outside expert testimony should state that fact. [*Sub-Committee.*—H. R. Heyl, Chairman; G. Morgan Eldridge, Theo. D. Rand.]

*Rotary Motor.*—Paul J. Reid, Philadelphia, Pa.

ABSTRACT.—The applicant submitted drawings of his scheme for such a device, and asked for an opinion as to its practicability. The sub-committee conferred with applicant and gave him the desired information. Report made advisory and case dismissed. [*Sub-Committee.*—H. W. Spangler, Chairman; Henry F. Colvin, J. M. Emanuel.]

*System of Aërial Navigation.*—H. H. Fisher, Corpus Christi, Texas.

ABSTRACT.—Applicant submits several sketches exhibiting his plans, a model and a number of explanatory letters, and requests an opinion as to the merits of the system. [The novel features of the plan, being unpatented, are communicated confidentially, and no disclosure of the same is desired.]

The report gives the applicant the information desired. [*Sub-Committee.*—Spencer Fullerton, Chairman; Henrik V. Loss, O. Chanute, A. F. Zahm, A. M. Herring.]

*Pneumatic Balance Lock.*—Chauncy N. Dutton, New York.

ABSTRACT.—This investigation relates to certain improvements on pneumatic locks devised by applicant. The committee of investigation bases its report upon an examination of U. S. Letters-Patent No. 457,528 and No. 557,566, and on the written description, illustrated by a number of drawings, of the proposed locks at Lockport, N. Y., submitted by the inventor.

[This description, with illustrations of details, will appear in full in the *Journal* in the near future, and reference is accordingly made to that publication, as without illustrations an abstraet would not be intelligible.]

The sub-committee's investigation was limited to the consideration of (*a*) the general principles involved in the invention proper and in the principal auxiliary devices, and (*b*) the apparent merits of the scheme as a whole.

The sub-committee finds the following meritorious features in the type of lift-lock under consideration:

(1) The favorable manner in which the locks are supported, namely, by an elastic air-cushion over their entire base, instead of the local concentration of their weight at one or more points, as in the method heretofore used or proposed.

(2) The fact that no dry-dock is needed at the lower level.

(3) The "parallel-motion" device for ensuring horizontal alignment under eccentric loading.

(4) Security in case of accidents of even so serious a nature as the sinking of a loaded boat at one end of the lock, or the carrying away of the outboard gate by an incoming vessel.

An uneconomical feature of this lock is the great depth and size of the pit required for the caisson in its lowest position.

The report finds that the invention, as a whole and in detail, gives evidence of much ingenuity and careful study on the part of its originator, and is of decided merit. [*Sub-Committee.*—Edgar Marburg, Chairman; H. W. Spangler, Wilfred Lewis.]

*Franklin Institute Gold Medal.* (Referred by the Board of Managers.)

At its meeting of June 9, 1897, the Board of Managers referred to this committee the question of the expediency of establishing a special award of honor, in the form of a gold medal, to be given annually by the Franklin Institute.

The report gives a brief historical reference to a number of awards of specially honorable significance, established by a number of learned societies of Europe and America, and which have for their object, generally, "the recognition of eminent services in the domain of science, which directly or indirectly contribute to the advancement of commerce, arts and manufactures; or, broadly speaking, to the promotion of the material welfare of mankind." A number of these are specified and commented upon.

The special committee charged with the consideration of the subject expressed the opinion that "a grand medal of gold, which would be associated with the name of Franklin, could, with much propriety, be established by the Franklin Institute, as a token of its appreciation of works of national or international value," and that, with the proper safeguards which could be provided, such an award should take rank with the distinguished awards referred to in the report.

The report, therefore, recommends "that it would be advisable for the Franklin Institute to award, at each of its annual meetings, a grand gold medal, to be known as the 'Franklin Medal,' to the inventor or discoverer, whose work has, within the previous five years, signally promoted the arts and manufactures." [*Sub-Committee.*—L. F. Rondinella, Chairman; Samuel Sartain, Wm. M. Barr, Wm. H. Wahl, L. E. Levy, Edgar Marburg, C. J. Reed. W.

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## CHEMICAL SECTION.

*Stated Meeting, February 15, 1898.*

## THE CHEMICAL COMPOSITION AND TECHNICAL ANALYSIS OF WATER GAS.

BY EDWARD H. EARNSHAW.
Chemist to the United Gas Improvement Company, Philadelphia, Member of the Institute.

As is well-known, water gas is a product of the reaction between steam and incandescent carbon, whereby there is formed a mixture of carbonic oxide and hydrogen in approximately equal volumes. This mixture, technically called "blue gas," has of course no illuminating value, and it is therefore enriched by exposing it together with hydrocarbon vapors to the action of intense heat. The hydrocarbon vapors are thus permanently gasified, or "fixed," and impart a high illuminating power to the mixture. This is carburetted water gas, more familiarly known simply as water gas.

The enriching material employed is always petroleum in some form, usually as crude oil, naphtha, or a distillate

called gas oil, which during the "fixing" process is converted into hydrogen and gaseous hydrocarbons, together with naphthalene, benzene and its homologues, and the other pungent empyreumatic compounds found in coal gas, and formed in that case by the contact of the gas with the hot sides of the retorts. The odor of coal gas is due to these empyreumatic compounds, and therefore, as might be expected, the odor of water gas is similar, but even more penetrating.

The chemical composition of coal gas and water gas is essentially the same; that is to say, the same constituent gases enter into the composition of each mixture, but the relative proportions vary. This is illustrated by the following analyses of coal gas and water gas respectively. The figures given are of actual analyses, but are fairly representative of each class:

| | Coal Gas. Per Cent. | Water Gas. Per Cent. |
|---|---|---|
| Benzene vapor | 0·50 | 0·6 |
| Heavy hydrocarbons | 4·25 | 12·8 |
| Carbonic oxide | 8·04 | 30·7 |
| Hydrogen | 47·04 | 32·4 |
| Marsh gas | 36·02 | 13·9 |
| Higher paraffines | 0·00 | 2·4 |
| Carbonic acid | 1·60 | 2·7 |
| Oxygen | 0·39 | 0·7 |
| Nitrogen | 2·16 | 3·8 |
| | 100·00 | 100·00 |

The composition of the heavy hydrocarbons, or "Illuminants" varies greatly with circumstances, both with coal and water gas, though they always consist chiefly of ethylene and other members of the olefin series, together with small quantities of other hydrocarbons of which acetylene is probably the most important.

From the gas analyst's point of view, the most important feature of the composition of water gas is the presence of notable quantities of paraffines other than marsh gas, since this involves a modification of the methods of analysis commonly in use, and which presuppose that marsh gas is the only paraffine present in the gas mixture.

This is the point that I chiefly desire to bring to your attention to-night.

## THE ANALYSIS OF WATER GAS.

The scheme of analysis, as far as the absorbable constituents of the gas mixture are concerned, follows the plan elaborated by Hempel, and is as follows:

(1) The vapors of benzene are first absorbed by shaking the gas in an explosion pipette over mercury with 1 c.c. of alcohol, previously saturated for the less easily absorbable constituents. The vapor of alcohol is absorbed in another explosion pipette by 1 c.c. of water, and the resulting contraction measured.

(2) The carbon dioxide is absorbed by potassium hydrate in a pipette filled with small rolls of iron wire gauze.

(3) The heavy hydrocarbons, or fixed illuminants are absorbed by a saturated aqueous solution of bromine. The vapors of bromine are absorbed by potassium hydrate, and the contraction measured.

Fuming sulphuric acid may be used instead of bromine, but it is much more difficult and inconvenient to handle, and the results obtained are scarcely more accurate.

(4) Oxygen is absorbed by phosphorus. Some chemists urge the use of an alkaline solution of pyrogallic acid, claiming that the action of phosphorus is unreliable. I have found, however, that in every case where the phosphorus has failed to act it has been due to incomplete absorption of the illuminants. Therefore, whenever on testing for oxygen, the white fumes of phosphoric acid fail to appear, the gas should be passed once more into the bromine solution. I have never yet analyzed a gas that did not contain at least a trace of oxygen. I strongly favor the use of phosphorus because the results obtained are at least as accurate as with pyrogallol, and because the appearance of the white fumes is absolute proof of the presence of oxygen, and indicates as well that the illuminants have been completely absorbed.

(5) The carbonic oxide is now absorbed by an ammoniacal or hydrochloric acid solution of cuprous chloride.

At least two pipettes should be used for the absorption, the last one containing a perfectly fresh solution. It is important to notice that even with this precaution the absorp-

tion of the carbonic oxide is seldom complete, usually about 0·5 per cent. remaining unabsorbed. This fact introduces no error in the analysis, as this residue of carbonic oxide can be determined later, as will be shown.

The residue of the gas mixture now remaining may be as follows:

(a) $(H_2) + (CO) + (N_2) + (CH_4) + (C_2H_6) + (C_3H_8)$, etc.

But for all ordinary purposes it is sufficient to assume that the only higher paraffine present is $C_2H_6$.

There being no satisfactory known absorbent for any of these gases it becomes necessary to have recourse to the method of combustion.

A portion of "a" is then mixed with a measured volume of air and exploded over mercury in an explosion pipette. The contraction in volume is measured, the carbon dioxide formed is determined by absorption with potassium hydrate, the excess of oxygen absorbed by phosphorus, and the volume of the residual N is noted.

The equations are:

(1) Contraction in volume $= \frac{3}{2}(H_2) + \frac{1}{2}(CO) + 2(CH_4) + 2\frac{1}{2}(C_2H_6)$

(2) $CO_2$ formed $= (CO) + CH_4) + 2(C_2H_6)$

(3) Residual nitrogen $= (N_2) + (N_1)$,

where $N_1$ is the nitrogen introduced with the air. The amount of nitrogen thus introduced may with sufficient accuracy be taken at 79·2 per cent. of the measured volume of air.

An examination of these equations shows that the nitrogen may at once be ascertained from equation (3), but equations 1 and 2 contain four unknown quantities, and therefore two more equations are needed for the solution. Fortunately the method of fractional combustion over palladium affords the needed information. As is well known, when a mixture of hydrogen and $CH_4$ with oxygen or air is passed with the proper precaution over heated palladium black, the hydrogen burns to $H_2O$, but the $CH_4$ is unaltered. If CO and any of the higher paraffines are also present, the

CO burns, but the paraffines do not. If then, the products from the combustion are received in a pipette over mercury, it is possible to subsequently measure the amount of $CO_2$ formed by the burning of the CO.

Returning to the analysis, a second portion of (a) is taken, mixed with air, and burned over palladium black. The resulting contraction and the $CO_2$ formed are measured. The equations are:

(4) Contraction in volume $= \frac{3}{2}(H_2) + \frac{1}{2}(CO)$.

(5) $CO_2$ formed $= CO$.

From these two equations the values for hydrogen and CO may be readily calculated.

For simplicity's sake let us now assume that the same quantity of gas mixture (a) was used in both the explosion and the combustion. We may then subtract equation (4) from (1), and (5) from (2), whence, designating the difference between the contraction due to explosion and that due to combustion by the letter (a) and the difference in the $CO_2$ formed by the letter (b), we find

(6) $2(CH_4) + 2\frac{1}{2}(C_2H_6) = a$.

(7) $(CH_4) + 2(C_2H_6) = b$.

(8) whence $C_2H_6 = \dfrac{4b - 2a}{3}$.

(9) $CH_4 = \dfrac{4a - 5b}{3}$.

A very useful check on the accuracy of this determination is obtained from the following:

Volume of gas taken for explosion $= H_2 + N_2 + CO + CH_4 + C_2H_6$. $H_2$ and CO are found by (4) and (5), and $N_2$ is given by (3). Therefore we have,

(10) Volume taken $- (H_2 + N_2 + CO) = CH_4 + C_2H_6$, and this value should be the same as the algebraic sum of (8) and (9), or,

(11) Volume taken $- (H_2 + N_2 + CO) = \dfrac{2a - b}{3}$.

This scheme of analysis is perfectly correct for gas mixtures containing no higher paraffine than $C_2H_6$, but what would happen in case $C_3H_8$, $C_4H_{10}$, etc., were present?

Our gas mixture would then contain P volumes of hydrocarbons of the formula $C_nH_{2n+2}$, and would be,

Gas mixture $= H_2 + N_2 + CO + P(C_nH_{2n+2})$.

As will be shown later, the contraction in volume due to the combustion of P volumes of any hydrocarbon of the general formula $C_nH_m$ would be

$$P(1 + \frac{m}{4})$$

and the $CO_2$ formed would be Pn. But in this case, $m = 2_{n+2}$, and therefore we have,

From the explosion:

(12) Contraction in volume

$$= \tfrac{3}{2}(H_2) + \tfrac{1}{2}(CO) + P + \frac{Pn + P}{2}$$

(13) $CO_2$ formed $= Pn + CO$.

And from the combustion over palladium:

(14) Contraction in volume $= \frac{3}{2}(H_2) + \frac{1}{2}(CO)$.

(15) $CO_2$ formed $= CO$.

Subtracting (14) from (12) and (15) from (13), as before explained, we have,

(16) Difference in contraction

$$P + \frac{Pn + P}{2} = a$$

(17) Difference in $CO_2$ formed $= Pn = b$; whence,

(18) $$P = \frac{2a - b}{3}$$

(19) $$n = \frac{3b}{2a - b}$$

Equation (18) is identical with (11), and hence it appears that the method is correct as far as the total volume of paraffines is concerned, even though higher paraffines than $C_2H_6$ are present.

Having thus examined the theory of the analysis by combustion, let us follow the figures of an actual analysis.

The gas was a water gas, enriched by naphtha, and its candle-power was 23·5.

| | |
|---|---|
| Amount taken for analysis | 100·0 c.c. |
| | *Per cent.* |
| $C_6H_6$ absorbed by alcohol | 0·4 |
| $CO_2$ absorbed by potash | 2·7 |
| Illuminants absorbed by bromine | 11·7 |
| Oxygen absorbed by phosphorus | 0·5 |
| CO absorbed by cuprous chloride | 31·7 |

Of the unabsorbed residue of 53 c.c., 14·05 c.c. were mixed with 87·8 c.c. of air, and exploded by a spark in an explosion pipette over mercury. The resulting contraction in volume was 22·60 c.c. The $CO_2$ absorbed by potash was 5·30 c.c.; the surplus oxygen absorbed by phosphorus 3·80 c.c.; the residual nitrogen, 70·1 c.c. consisting of nitrogen from the air, 69·50 c.c. and nitrogen from the gas, 0·60 c.c.

A second portion of 30 c.c. was now mixed with 70 c.c. of air and the mixture passed over palladium black to burn the hydrogen and CO.

The contraction in volume was 30·40 c.c.

$CO_2$ absorbed by potash was 0·40 c.c.

To calculate the percentage of hydrogen, CO, $CH_4$, $C_2H_6$ and nitrogen according to the method already theoretically explained we proceed thus:

$$CO = \frac{0·4 \times 53}{30} = 0·70 \text{ per cent.}$$

$$\text{Hydrogen} = \frac{(30·4 - 0·2) \times 53}{30} \times \frac{2}{3} = 35·57 \text{ per cent.}$$

Now, as 30 c.c. of gas were taken for the combustion and only 14·05 c.c. for the explosion, we must calculate the contraction in volume and amount of $CO_2$ that would have resulted from the combustion of 14·05 c.c. over palladium; thus:

Contraction in volume would be

$$= \frac{30·4 \times 14·05}{30} = 14·24$$

$CO_2$ formed would be

$$= \frac{0·40 \times 14·05}{30} = 0·18$$

Subtracting these figures from the results of the explosion, we find,

$$22{\cdot}60 - 14{\cdot}24 = 8{\cdot}36 = a$$

$$5{\cdot}30 - 0{\cdot}18 = 5{\cdot}12 = b$$

and hence, from (8) and (9)

$$C_2H_6 = \frac{20{\cdot}48 - 16{\cdot}72}{3} = 1{\cdot}25$$

$$CH_4 = \frac{33{\cdot}44 - 25.60}{3} = 2{\cdot}61,$$

and therefore,

$C_2H_6$ in original gas

$$= \frac{1{\cdot}25 \times 53}{14{\cdot}05} = 4{\cdot}71 \text{ per cent.}$$

$CH_4$ in original gas

$$\frac{2{\cdot}61 \times 53}{14{\cdot}05} = 9{\cdot}84 \text{ per cent.}$$

Nitrogen in original gas

$$= \frac{0{\cdot}60 \times 53}{14{\cdot}05} = 2{\cdot}26 \text{ per cent.}$$

Applying equation (11) as a check on the accuracy of the determination, we find:

$$14{\cdot}05 - (9{\cdot}43 + 0{\cdot}60 + 0{\cdot}18) = \frac{2\,(8{\cdot}36) - 5{\cdot}12}{3}$$

or, $3{\cdot}84 = 3{\cdot}86$, which is a difference well within the limit of errors of observation.

In the calculation of this analysis we have assumed for convenience' sake that there are no paraffines present other than $CH_4$ and $C_2H_6$. Of course, it is possible and indeed probable, that higher members of the series are actually present, so that while the figures obtained in our calculations truly represent the total quantity of paraffines contained in the gas, yet they may not be true as regards the actual composition. The composition of the average molecule of the paraffines may be obtained from equation (19), thus:

$$n = \frac{15{\cdot}36}{16{\cdot}72 - 5{\cdot}12} = 1{\cdot}32$$

whence the average composition of the paraffines $C_nH_{2n+2}$ would be $C1{\cdot}32\ H4{\cdot}64$.

The value of this method in giving an accurate conception of the actual composition of a gas mixture, is clearly brought out by comparing the figures just given with those obtained by the more usual methods of calculation.

These methods are: (1) when no combustion over palladium is made, and the hydrogen is determined by subtracting twice the volume of $CO_2$ formed in the explosion from the contraction in volume, and calling the difference the contraction due to hydrogen. (2) The method recommended by Hempel, who directs that the hydrogen should be determined by combustion over palladium. The contraction in volume due to the percentage of hydrogen thus found, is subtracted from the total contraction due to the explosion, and the remainder is considered to be the contraction due to $CH_4$, which is, of course, equal to twice the volume of $CH_4$. Both these methods presuppose that no paraffine other than $CH_4$ is present, and that the CO has been completely absorbed by cuprous chloride.

| | Calculated by method given above. | By method without combustion over Palladium. | By method according to Hempel |
|---|---|---|---|
| Benzene vapors | 0·40 | 0·40 | 0·40 |
| Fixed illuminants | 11·70 | 11·70 | 11·70 |
| Carbonic oxide | 32·40 | 31·70 | 31·70 |
| Hydrogen | 35·57 | 30·34 | 35·84 |
| Paraffines $\begin{cases} C_2H_6 \\ CH_4 \end{cases}$ $C_2H_6$ | 4·71 | — | — |
| $CH_4$ | 9·84 | 20·00 | 16·30 |
| Carbonic acid | 2·70 | 2·70 | 2·70 |
| Oxygen | 0·50 | 0·50 | 0·50 |
| Nitrogen (by difference) | 2·18 | 2·66 | 0·86 |
| | 1000·00 | 100·00 | 100·00 |

The method without separate determination of hydrogen is the simplest both in method and in apparatus required, and is, therefore, the one in most general use.

In the analysis of water gas by this method, let us consider the equations resulting from the explosion of 15 c.c. of a gas mixture composed of

| | c c. |
|---|---|
| Hydrogen | 10 |
| $CH_4$ | 3 |
| $C_2H_6$ | 1·5 |
| Nitrogen | 0·5 |
| | 15·0 |

The resulting equations would be:

| | | |
|---|---|---|
| Contraction in volume | $= \frac{3}{2} (H_2) + 2 (CH_4) + 2\frac{1}{2} (C_2H_6)$ | $= 24·75$ |
| $CO_2$ formed | $= (CH_4) + 2(C_2H_6)$ | $= 6·00$ |
| Volume of gas taken | $= H_2 + CH_4 + C_2H_6 + N_2$ | $= 15·0$ |
| Nitrogen | $= N_2$ | $= 0·50$ |

At first it would seem that these equations could be easily solved, and that no more data would be required for the correct computation of the composition of the gas mixture. An attempt to solve the equations, however, discloses the fact that the problem is indeterminate, and that the equations can be satisfied by any value of $C_2H_6$ from 0 to 3.

Thus:

| | | | |
|---|---|---|---|
| Let $C_2H_6$ | = 0, | Let $C_2H_6$ | = 3 |
| Then, $H_2$ | = 8·50 | Then, $H_2$ | = 11·50 |
| $CH_4$ | = 6·00 | $CH_4$ | = 0·00 |
| $C_2H_6$ | = 0·00 | $C_2H_6$ | = 3·00 |
| $N_2$ | = 0·50 | $N_2$ | = 0·50 |
| | 15·00 | | 15·00 |

We may perhaps find in this circumstance an explanation for the continued use of this method by many analysts without suspecting the incorrect application to gas mixtures containing higher paraffines than methane. The analysis would always "add up well," and the amount of nitrogen found would be correct.

I have now indicated a method by which we may obtain a very fair idea of the composition of a gas mixture, sufficient indeed, for most purposes. But the use of gas as a source of heat is constantly increasing, and I believe the time is not far distant when the heating value of a gas will be considered as important as its illuminating power. It is therefore extremely desirable to be able to accurately calculate the heating value of a gas from its analysis. The labors of many able investigators, and notably those of Prof.

Julius Thomsen, have supplied us with reliable data concerning the heating value of each of the several combustible gases entering into the composition of illuminating gas, and therefore the problem would offer no special difficulty were it not for the uncertainty regarding the nature of the hydrocarbons removed by bromine, and classed together as "fixed illuminants." We know that these consist chiefly of the series $C_nH_{2n}$, together with very small quantities of the $C_nH_{2n-2}$ series, but the quantitative separation of the different members is not at present possible within the limits of a technical analysis.

If, however, we should succeed in determining the average composition of the hydrocarbons, and should be able to assign a definite heating value, depending upon such average composition, then the problem would be completely solved as far as its practical application is concerned.

The theory of the combustion of any hydrocarbon or mixture of hydrocarbons, of which the unit volume has the average composition $C_nH_m$, is as follows:

$$C_nH_m \left(n + \frac{m}{4}\right)O_2 = n(CO_2) + \frac{m}{2}(H_2O)$$

But in practice the

$$\frac{m}{2}$$

volumes of water disappear, and therefore we have,

Contraction in volume

$$= 1 + \left(n + \frac{m}{4}\right) - n = 1 + \frac{m}{4}$$

$$CO_2 \text{ formed} = n$$

If we let $a$ = contraction in volume for $x$ volumes $C_nH_m$

$b$ = $CO_2$ formed for $x$ volumes $C_nH_m$ then we find,

(20) $$m = \frac{4(a - x)}{x}$$

(21) $$n = \frac{b}{x}.$$

It is now apparent that if we can by any means determine the contraction in volume and the amount of $CO_2$ that would be formed by the combustion of a known volume of the illuminants in a gas mixture, then we will have all the data necessary for the correct computation of the average composition of such illuminants. This can be done very simply and accurately thus:

First absorb the unfixed vapors by alcohol, and the $CO_2$ by potassium hydrate. The residual gas will have the composition,

$$C_nH_m + CO + H_2 + C_nH_{2n+2} + O_2 + N_2$$

Take a portion of this, mix it with the proper amount of air, and explode the mixture by a spark in the ordinary way. Note the resulting contraction in volume, and the amount of the $CO_2$ formed.

The contraction in volume will consist of:

(1) Contraction due to $C_nH_m$,
(2) " " " $CO$,
(3) " " " $H_2$,
(4) " " " $C_nH_{2n+2}$,

and the $CO_2$ formed will consist in like manner:

(1) $CO_2$ due to $C_nH_m$.
(2) $CO_2$ due to $CO$,
(3) " " " $C_nH_{2n+2}$.

If, now, we proceed with the analysis and determine the percentage of each constituent by the method already described, we will be able to calculate the contraction due to $CO$, $H_2$, and $C_nH_{2n+2}$, and the $CO_2$ due to $CO$ and $C_nH_{2n+2}$. This will give us the contraction in volume and the $CO_2$ due to $C_nH_m$ alone, and hence the data required.

In practice it is simpler to calculate the correction for the Paraffines and Hydrogen directly from the results of the explosion rather than from the percentages of these gases, but this will be made plainer by considering the actual figures of an analysis.

Taking for illustration the same sample of water gas as before, the notes of the analysis would be:

| | Cubic Centimeters. | Per Cent. |
|---|---|---|
| Amount taken for analysis | 100·00 | |
| Residue after absorbing the unfixed vapors and the $CO_2$ | 96·90 (a) | |

*First Explosion.*

| | | |
|---|---|---|
| Portion of (a) taken | 12·00 | |
| Mixed with 87·8 cubic centimeters of air and exploded: | | |
| Resulting contraction in volume | 16·05 | |
| $CO_2$ absorbed by potash | 10·55 | |
| Excess oxygen absorbed by phosphorus | 3·40 | |
| Residue from (a) | 84·90 | |
| Fixed Ills. absorbed by bromine | 10·25 | = 11.70 |
| Oxygen absorbed by phosphorus | 0·44 | = 0·50 |
| CO absorbed by cuprous chloride | 27·78 | = 31·70 |
| Residue (b) | 46·45 | = 53·00 |

*Second Explosion.*

| | |
|---|---|
| Portion of (b) taken | 14·05 |
| Mixed with 87·8 cubic centimeters of air and exploded: | |
| Resulting contraction in volume | 22·60 |
| $CO_2$ absorbed by potash | 5·30 |
| Excess $O^2$ absorbed by phosphorus | 3·80 |

The amount taken for the first explosion was

$$\frac{12}{96{\cdot}9} = {\cdot}1237$$

of the original quantity, and we can, therefore, calculate that it was composed of,

| | Per Cent. | Cubic Centimeters. |
|---|---|---|
| Fixed Illuminants | 11·70 x ·1237 | 1·45 |
| Oxygen | 0·50 x " | 0·06 |
| Carbonic oxide | 31·70 x " | 3·93 |
| Residue (b) | 53·00 x " | 6·56 |
| | | 12·00 |

The contraction and $CO_2$ resulting from the explosion of 14·05 cubic centimeters of residue (b) having been determined by the second explosion, we can, of course, readily calculate the results due to the combustion of 6·56 cubic centimeters.

The results of the first explosion can now be tabulated thus:

| | | | | $CO_2$ | Contraction. |
|---|---|---|---|---|---|
| | | | | Cubic Centimeters. | |
| 1·45 cubic centimeters | Fixed Ills. ($C_nH_m$) | gives | . . . . | 4·15 | 3·56 |
| 3·93 " | " carbonic oxide | " | . . . . | 3·93 | 1 96 |
| 6·56 " | " residue (b) | " | . . . . | 2·47 | 10·53 |
| | | | | 10·55 | 16·05 |

and hence from equations (20) and (21),

$$m = \frac{4\,(3{\cdot}56 - 1{\cdot}45)}{1{\cdot}45} = 5{\cdot}82$$

$$n = \frac{4{\cdot}15}{1{\cdot}45} = 2{\cdot}86$$

and, therefore, the average composition of the Fixed Illuminants $C_nH_m$ is C 2·86 H 5·82.

Prof. Julius Thomsen in his "Thermo-Chemical Investigations," vol. iv, p. 275, gives the general formula for the calculation of the heat of combustion of any hydrocarbon of the formula $C_nH_{2m}$, expressed in calories per molecular weight in grams of the hydrocarbon, thus:

$$f = n \cdot 135340 + m \cdot 37780 - a \cdot 14200 + 580.$$

For the olefin series, $C_nH_{2n}$,

$$n = m$$

$$a = n - 1$$

and, therefore, translating the formula into English units, we find for the heat of combustion of any hydrocarbon, or mixture of hydrocarbons of the general formula $C_nH_{2n}$

$$\text{B.T.U. per cubic foot} = n\,(757) + 70$$

$$\text{B.T.U. per pound} \doteq 20432 + \frac{1900}{n}$$

For the paraffine series, $C_nH_{2n+2}$,

$$m = n + 1$$

$$a = n - 1$$

and, therefore, we find for the heat of combustion:

$$\text{B.T.U. per cubic foot} = n\,(757) + 251$$

$$\text{B.T.U. per pound } 20432 + \frac{53744}{14n + 2}$$

We found the composition of the illuminants to be $C_{2 \cdot 86} H_{5 \cdot 82}$, and this approaches so closely to the composition of olefins, that for all practical purposes we may consider the fixed illuminants as belonging entirely to that series.

Therefore, calculating the average heating value of the illuminants from the formula for the olefins, we have:

$$\text{Illuminants, } C_{2 \cdot 86} H_{5 \cdot 72} = 2235 \text{ B.T.U. per cubic foot.}$$

We found the average composition of the paraffines to be $C_{1 \cdot 32} H_{4 \cdot 64}$, and hence from the formula for the paraffines, the average heating value would be:

$$\text{Paraffines, } C_{1 \cdot 32} H_{4 \cdot 64} = 1250 \text{ B.T.U. per cubic foot.}$$

We have shown that the determination of the total amount of paraffines in a gas mixture is not affected by considering $CH_4$ and $C_2H_6$ to be the only two members of the series present, and it is also true that the calculation of the heating value is unaltered by the same assumption. This may be shown as follows:

The percentage of paraffines present, and their composition, was found by the analysis to be

$$14 \cdot 55 \text{ p. c. } C_{1 \cdot 32} H_{4 \cdot 64} = 4 \cdot 71 \text{ p. c. } C_2H_6 + 9 \cdot 84 \text{ p. c. } CH_4.$$

The calculation of the heating value would be

$$\cdot 1455 \text{ cubic foot } C_{1 \cdot 32} H_{4 \cdot 64} \times 1250 = 182 \cdot 9 \text{ B.T.U.}$$

$$\left.\begin{array}{l} \cdot 0471 \text{ `` `` } C_2H_6 \times 1764 \cdot 4 = 83 \cdot 1 \\ \cdot 0984 \text{ `` `` } CH_4 \times 1009 = 99 \cdot 2 \end{array}\right\} 182 \cdot 3 \text{ B.T.U.}$$

Thus the result is the same whichever method of calculation is adopted.

The heating values obtained by Prof. Julius Thomsen for the principal constituents of illuminating gas are given in the following table. Thomsen's original figures are

given in calories per molecular weight of the substance in grams, and I have translated these into English units per cubic foot. The temperature of the products of combustion is assumed to be reduced to 18° C. or 64·4° F.:

| Name. | Molecular Formula. | Calories per Molecular Weight in Grams. | B.T.U.'s per Cubic Foot at 60° and 30″. |
|---|---|---|---|
| Hydrogen | $H_2$ | 68360 | 326·2 |
| Carbonic oxide | $CO$ | 67960 | 323·5 |
| Methane | $CH_4$ | 211930 | 1009·0 |
| Ethane | $C_2H_6$ | 370440 | 1764·4 |
| Propane | $C_3H_8$ | 529210 | 2521·0 |
| Butane | $C_4H_{10}$ | 687190 | 3274·0 |
| Ethylene | $C_2H_4$ | 333350 | 1588·0 |
| Propylene | $C_3H_6$ | 492740 | 2347·2 |
| Butylene | $C_4H_8$ | 650620 | 3099·2 |
| Acetylene | $C_2H_2$ | 310050 | 1476·7 |
| Benzene | $C_6H_6$ | 799350 | 3807·4 |

Returning once more to our analysis, the calculation of the heating value of 1 cubic foot of the water-gas would be:

| | | | | |
|---|---|---|---|---|
| ·0040 cubic foot | $C_6H_6 \times 3807·4$ | = | 15·2 | B.T.U. |
| ·0170 " " | $C_{2·86}H_{5·72} \times 2235$ | = | 261·5 | " |
| ·3240 " " | $CO \times 323·5$ | = | 104·8 | " |
| ·3557 " " | $H_2 \times 326·2$ | = | 116·0 | " |
| ·0471 " " | $C_2H_6 \times 1764·4$ | = | 83·1 | " |
| ·0984 " " | $CH_4 \times 1009·0$ | = | 99·2 | " |
| ·0538 " " | $CO_2 + O_2 + N_2$ | = | 0·0 | " |
| 1·0000 | | | 679·8 | " |

# Mining and Metallurgical Section.

*Stated Meeting, May 11, 1898.*

## OLD AND NEW METHODS APPLIED IN PLANNING PIPE-LINES AND PENSTOCKS.

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[With a reasonable expectation of approval on the part of all men versed in recent evolution of hydraulics, it may be stated at this time that there has sprung into existence that which may be aptly called modern hydraulics.

The science of mechanics in general, and of hydraulics in special, has been represented amongst the living generation by two schools of extremists. This fact may be plainly shown by quoting from two authors of equally high merit.

R. G. Blaine, Senior Demonstrator and Lecturer in the mechanical engineering department of the City and Guilds of London Institute's Technical College, in the preface to his recently published book on "Hydraulic Machinery," expresses his opinion on the proper method to be followed in treating subjects of mechanics or hydraulics, as follows:

"An attempt is usually made to avoid using the calculus or to disguise its use in the language of so-called elementary mathematics; this course is not altogether free from objections, the proofs given being usually long and not too exact."

John C. Trautwine, in the preface to his "Civil Engineers' Pocketbook," after recommending by name of author some works on matters of engineering, expresses his opinion on the same subject as follows:

"The writer does not include Rankine, Moseley and Weisbach, because, although their books are the productions of master minds, and exhibit a profundity of knowledge be-

yond the reach of ordinary men, yet their language also is so profound that very few engineers can read them; they are but little more than striking instances of how completely the most simple facts may be buried out of sight under heaps of mathematical rubbish."

*Modern hydraulics* stands midway between these two extremes, thus signalized by two leaders in the field of applied mechanics and hydraulics. The more modern method may be described in but few words. It desists absolutely and completely from accepting as true any alleged fact that cannot be verified by proper test under stated conditions. Hence, it does not make observations, using the spectacles of tradition, but approaches all problems that have not found their solution in a clear, simple, uncomplicated equation of general applicability, resting on clearly stated conditions, with a sceptical mind unbiased by predilection for either calculus or elementary mathematics, but for evident cause avoids the former where the latter are adequate. Hence, its distinctive quality consists in this, that essentially it dives for the true causes of observed effects, and strictly refuses to accept words or names where correct conception is wanting, or to be content with explaining specific resistances by specific names without the knowledge of the specific and real cause hidden in a name. And it also is peculiar to such modern mechanics and hydraulics that they make distinction between arbitrary units of measurement, set up by man, and such other units as nature itself has provided.

As products of such modern hydraulics the author may quote:

(1) The equation which measures force (and work, when connected with time), which is of general application, and accounts not only for mass and movement, but for all essential dimensions or qualities of both mass and movement, be the mass solid or fluid; an equation which is uncomplicated by undetermined or uncertain coefficients, and which equation is valid in either the metrical or foot-pound system, when its values are properly expressed in such system, namely, the equation to which the author will of necessity have to refer, and which reads:

$$P = Q\gamma \,.\, h = F \,.\, v \,.\, h = F \,.\, \frac{v^3}{2g}$$

kilogrammetres or foot-pounds.

(2) The equation which, by the mere substitution of the newly-created value

$$\frac{B}{d}$$

(average section) for $F$ in the same cited equation, and on the basis of an analysis of the effects of continuous displacement, has solved all the until then abstruse problems relating to the movement of a volume of stable form within a medium of yielding form, whether the stable form be represented by a steamship, a balloon or a planet. (Compare this *Journal* for March to May, 1893.)

(3) The equation of equal general applicability, by which the uniform maximum velocity is determined, with which a volume of known length in the direction of motion and of known relative density can fall (move) in a fluid medium, or can fall on this globe in air or water, or in any other medium, and by which the main dimension of the solid may be determined, which a current may move at all or at a stated velocity, an equation general in applicability and precise in conditions, namely, the equation for maximum velocity of fall:

$$C = \sqrt{\delta \,.\, d \,.\, 2g \,.\, \frac{\delta - 1}{\delta + 1}}$$

(Compare *Transactions* Am. Inst. of Mining Engineers, 1894. "Solids Falling in a Medium," I and II.)

To these achievements this paper is intended to add a fourth one, namely, an equation of equally universal applicability, by means of which the form of channel is determined, which will permit a current to flow in such form and with such velocity as unimpeded nature will impart to it, provided its total fall and one of its sections at a known level be stated.]

Prevailing practice in planning pipe-lines or penstocks resorts to tables, in which the results of experimenting with pipes of uniform section, and relating to quantities ejected,

have been collected, such experimenting covering a very limited variety of heads and of pipe dimensions.

It is true that the results thus obtained have been construed into equations of more or less presumed applicability.

Tables and equations were arranged on the assumption of three different elements or conditions, as influencing or determining the results. On the one hand the maximum quantity of ejection was correctly assumed as the product in volume of the velocity of ejection by the area of the aperture of ejection, and the difference between such maximum volume and the volume actually ejected was considered as *loss* (of head) and is expressed as *percentage of head lost*, or as the first element in the construction of tables and equations. The *loss* ascertained is then ascribed to two different causes, as the other two elements in such construction, namely:

*Loss* due to the *orifice of influx*, and

*Loss* due to *friction*.

When the quantity of water to be supplied is known, prevailing practice consults the tables, which, of necessity, are considered as more reliable than the equations that were evolved therefrom. In ascertaining the diameter of the pipe that will eject under the available head the needed quantity, it is found, as an almost invariable fact, that not more than 10 per cent. of the theoretical maximum is obtained in fact, or that in a pipe of uniform section, the ejecting end ejects 90 per cent. less than it would eject were the ejection to take place with the velocity $v = \sqrt{h\,2g}$, when $h$ is considered, as it appears by actual survey. As a necessary consequence, under the older method, a pipe is selected of ten times the diameter of a circular aperture which, under the head $h$, would eject the required quantity were it ejecting with theoretical velocity.

Conflicting with this prevailing practice it is here recommended that *the dimensions of the supply-pipe* in its entire length *be adapted to the conditions, as set by the laws of gravitation, or to the shape that the falling body of water would assume under these laws*, under which laws the same quantity that is finally ejected must pass, and does pass, any level plane between surface of supply and level of ejection within the same

period of time, but passes such level plane or transverse section with velocities that are at no two levels the same, but which are constantly increasing as the fall continues, unless constrained by confining walls to do otherwise, and which sections must, in free fall, decrease in ascertainable proportional relation as the velocity of fall increases, to the effect that the same quantity may, within the same period, pass any point in the entire fall.

It is the object of this discussion to demonstrate the precise dimensions thus adapted, and the reasons and causes for which a new method, conflicting with prevailing practice, should be followed in planning supply-pipes.

To ensure my readers' attention, I may be permitted to preface my discussion with the statement that, under equal given conditions, a stated supply of water is secured at lower cost under the proposed new method than prevailing practice will permit, and that, for identical qualities of material, there is a large difference in favor of the new method—a difference of such magnitude that competition in the construction of pipe-lines and penstocks, made under the older system, becomes impracticable in opposition to those made in design as prescribed under the new method.

Proceeding with my discussion, I claim it to be almost impossible to intelligently discuss questions of hydraulics without using the system of interchangeable values for volume and weight, as used in the metric system. On the other hand, many good reasons can be cited for not discarding the foot- and pound-units in our American practice. The writer has made, as he inclines to think, a successful step toward adapting to the foot-pound units the system of dual values for volume and weight. As it is proposed to use these units in the present discussion, it is necessary to explain, in a few words, the nature of these new units and their adaptation to the problem under consideration.

While a column of water 1 meter long, with a base of 10 square centimeters has a volume of 1 liter, or of 0·1 cubic meter, and weighs 1 kilogram; a column of water (of identical density, of which the cubic foot weighs 62·421 pounds) 1 foot long must have, in order to weigh 1 pound, a

base of 144 square inches / 62·421 pounds = 2·306916 square inches (= 0·016 square foot).

The area of 2·306916 square inches may in consequence be used in the foot-pound system, as the area of 10 square centimeters is used in the metric system. And in consequence the fundamental equation

$$P = Q\,y\,.\,h = F\,.\,v\,.\,h = F\,.\,v\,.\,v^2/2\,g = F\,.\,v^3/2\,g$$

foot-pound, is as valid for our system of units as its equivalent is in the metric system, on condition that $F$ be expressed in the stated proper units of 2·306916 square inches.

The expression for force may be substituted by one for work, or by the expression for horse-power-second, in reducing the value to

$$P/s = F\,.\,v^3/2\,g\,s.$$

In these and all other equations which are cited in this paper,

$P$ stands for maximum-force in foot-pounds.

$F$ stands for transverse section of current, ejected with force, such area being expressed in units of 144/62·421 = 2·306916 square inches.

$F''$ stands for the same area, expressed in square inches.

$Q$ stands for cubic feet, and $y$ for 62·421 pounds.

$h$ stands for the distance of fall in feet, in vertical measurement between the surface of the supplied water and the level of ejection.

$H$ stands for the head in feet above an intermediate level in a supply-pipe, situate between its upper and lower ends, being the upper part in $h$, of which

$H^\circ$ stands for the other or lower part, causing $h$ to be $= H + H^\circ$, and $H^\circ$ to be the head above the level of ejection at an intermediate level between the source of supply and the level of ejection.

$H''$ stands for 1 foot, or for the head taken at 1 foot below the surface of the inflowing water, or for

an inlet that is 1 foot below the surface of the inflowing water.

$v$ stands for the velocity of ejection in feet.

$g$ stands for twice the distance of fall in the first second, assumed at the latitude of 45° for sea-level as 9·81 meters = 32·183669 feet.

$s$ stands for 550 foot-pounds, the equivalent of 1 horse-power second.

The essential of the equation, as hereinabove expressed, is the assumption that a weight of $Q\ y$ pounds of water, falling a vertical distance = $h$ feet, produces a force of $P$ foot-pound, or the work of $P/s$ horse-power second.

From the stated equation a number of values can be deduced, of which use must be made in carrying out the inquiry which is the subject-matter of this paper, and which in themselves will be of material assistance in solving all kinds of problems in hydraulics.

Such evolved values will be positive and practical values, whenever the velocity, that is one of the conditions to the value, is the velocity in fact of ejection. Such velocity, in fact, may in practice be reliably ascertained, by dividing the ejected weight of water in pounds multiplied by 2·306916, by the aperture of ejection in square inches, in accordance with $Q\ y / F = v = 2{\cdot}306916\ .\ Q\ y / F''$, when, as stated, $F$ is the section of ejected current in units of 2·306916 square inches, and $F''$ the same section in square inches.

The cause for measuring head and velocity in feet, and for measuring transverse section of current and values ($d$ and $D$ of diameters) relating thereto, in inches, originates in our practice of designating pipes by inches of their diameters. Were it not for this custom, the value $F$ might be expressed in units of $1/62{\cdot}421 = 0{\cdot}016$ square foot. As it is, $F$ is more appropriately expressed in units of $144/62{\cdot}421 = 2{\cdot}306916$ square inches, both of which expressions, as such, originate in the necessity of expressing the area $F$ in a manner that will impart to a column of water, 1 foot long, a weight of 1 pound for every unit in the expression of its transverse section = $F$, or in the necessity of expressing total weight of water ejected as the product of velocity of

ejection by the transverse section of ejected body (at aperture of ejection).

The values, as mentioned and obtained, by simple mathematical evolution, which must not only render service in solving my special problem, but which, as such, render useful service in many other problems in hydraulics, are as follows:

$$A\,a = \frac{148{\cdot}49}{v^3} = \frac{0{\cdot}287537832651 +}{\sqrt{h^3}} \text{ square inches}$$

is the expression for the *requirement* in square inches of transverse section of ejected current (jet, when of moderate dimensions) for producing the *force of 1 foot-pound.*

$$A\,b = \frac{81669{\cdot}5}{v^3} = \frac{158{\cdot}1516}{\sqrt{h^3}} \text{ square inches}$$

is the expression for the *requirement* in square inches of transverse section of ejected current for producing the *work of 1 horse-power second.*

By 1 foot-pound $= F \,.\, v^3 / 2\,g$, and by $F'' = F \,.\, 2{\cdot}306916$, and by $2\,g = 64{\cdot}367338$ feet ($g = 9{\cdot}81$ meters for sea-level and 45° lat.)

$$F'' = \frac{148{\cdot}49}{v^3}$$

and by 550 foot-pounds per second = 1 horse-power second, the stated value $A\,b$ is obtained. By $v = \sqrt{2\,g} \,.\, \sqrt{h}$ the substitute values, with $h$ in place of $v$, are obtained.

$$B\,a = d = \frac{13{\cdot}75}{\sqrt{v^3}} = \frac{0{\cdot}604581}{\sqrt[4]{h^3}} \text{ inches}$$

is the expression for the *diameter required* in a circular transverse section of a jet that possesses the *force of 1 foot-pound.*

$$B\,b = d = \frac{322{\cdot}49}{\sqrt{v^3}} = \frac{14{\cdot}18}{\sqrt[4]{h^3}} \text{ inches}$$

is the expression for the *diameter required* in a circular transverse section of a jet that does the *work of 1 horse-power second.*

Because $F'' = d^2 . p / 4$, and $\sqrt{550} = 23.473$.

$$Ca = \frac{v^3}{148.49} \quad \frac{\sqrt{h^3}}{0.28754} \text{ foot-pound}$$

$$Cb = \frac{v^3}{81669.5} - \frac{\sqrt{h^3}}{158.1655} \text{ horse-power second}$$

are the expressions for the *effect* of a jet that has a transverse *section of 1 square inch*, as a direct consequence of the requirement per foot-pound and horse-power, as expressed under $A\,a$ and $A\,b$.

$$D\,a = \frac{v^3}{189.0629} = \sqrt{h^3} \,.\, 2.7314671 \text{ foot-pound}$$

$$D\,b = \frac{v^3}{103984.595} = \frac{\sqrt{h^3}}{201.32} \text{ horse-power second}$$

are the expressions for the *effect* of a *jet* that has a circular transverse section *of 1 inch diameter*, because $C\,a \div D\,a = 1 \div p / 4$.

$$E\,a = \frac{d^2 \,.\, v^3}{189.0649} = d^2 \,.\, \sqrt{h^3} \,.\, 2.73 \text{ foot-pound}$$

$$E\,b = \frac{d^2 \,.\, v^3}{103984.6} = \frac{d^2 \,.\, \sqrt{h^3}}{201.32} \text{ horse-power}$$

are the expressions for force and work produced by any circular jet, the *diameter d* of which is known as a direct consequence of preceding values, as stated.

$$F\,a = \frac{d^2 \,.\, v^2}{189.0649} = \frac{d^2 \,.\, h}{2.93725} \text{ foot-pound}$$

$$F\,b = \frac{d^2 \,.\, v^2}{103984.6} = \frac{d^2 \,.\, h}{1615.4875} \text{ horse-power second}$$

are the expressions for force and work, produced by circular jets per foot of velocity.

There cannot be sustained any reasonable doubt concerning the fact that the *effects* thus stated and measured by actual velocity of *ejection* and by transverse section of *ejected current* (aperture of ejection) are *effects in fact*, and not effects in theory only. Such actual velocity of ejection may,

in practice, be ascertained without any other exertion than that which is connected with establishing for any case under consideration the quantity (pounds) of water ejected per second. The value $F$ in units of 2·306916 square inches for the transverse section of current, must be determined by the aperture of ejection, and $Q y \ / \ F = v$ shows actual velocity of ejection. This result is not vitiated even by the ejection not taking place in a body of perfect cylindrical or other uniform section, and not by the appearance of what in hydraulics is called "the contracted vein," because the result obtained is independent of the section of the jet, except in the aperture of ejection.

But whenever the values for head or for velocity are assumed, as shown by survey of head, and as $v = \sqrt{h\ 2\ g}$, in that case, the values shown are those for obtainable maximum effect ($C a$ to $F b$) or for minimum requirement ($A a$ to $B b$).

The equations $E a$ and $E b$ for *effect* of falling currents of water of circular section condition the valuation of such effects on two values, viz.: the diameter $d$ of the aperture of ejection or of the ejected current, and the velocity of ejection. Whenever the product $d^2 . v^3$ in one case is equal to such product relating to another case, then the *effect* is the same in both cases, though the two coefficients mentioned may be different singly from one another, it being evident that all variations must be inversely proportionate.

For better elucidation of the consequences that may be drawn from the stated fact, different values, relating to one another in sets, may be expressed by different symbols, such as $d$, $v$ and $h$ as one set, $D$, $V$ and $H \div D'$, $V'$ and $H'$, etc., as other sets, it being assumed that $h$ represents maximum head, with $H$, $H'$ and $H''$ as minor heads.

We then have

$$E b = \frac{d^2 . v^3}{103984{\cdot}6} = \frac{D^2 . V^3}{103984{\cdot}6}$$

and in consequence

$$D = d . \sqrt{\frac{v^3}{V^3}}.$$

And in the same manner we may develop the equivalent value

$$D = \sqrt[4]{h^3 / H^3} \,.\, d.$$

These two equivalent values express the *diameter required* in a circular current ejected under a minor head $H$, to produce the same power as is produced under the higher head $h$ by a current of the minor diameter $d$.

The result demonstrates the fact that, to produce the same power as produced under a major head $h$, by ejecting a current of the diameter $d$, the diameter $D°$ of the current ejected under minor head $H$ must be made larger, and must so be made at the rate of the third power of the fourth root of the quotient of the minor head in the major head, or at the rate of the third power of the square root of the quotient of the minor in the major velocity.

The following proportional relation appears as a consequence:

$$d \div D° = d \div d \,.\, \frac{\sqrt[4]{h^3}}{\sqrt[4]{H^3}} = \sqrt[4]{H^3} \div \sqrt[4]{h^3} = \frac{H}{\sqrt[4]{H}} \div \frac{h}{\sqrt[4]{h}} \text{ and}$$

$$d \div D° = d \div d \,.\, \frac{\sqrt{v^3}}{\sqrt{V^3}} = \sqrt{V^3} \div \sqrt{v^3} = \frac{V}{\sqrt[4]{V}} \div \frac{v}{\sqrt[4]{v}}$$

Hence:

$$D° = d \,.\, \frac{\sqrt[4]{h^3}}{\sqrt[4]{H^3}} = d. \frac{\sqrt{v^3}}{\sqrt{V^3}}$$

Thereby it appears that:

I. *The requirement in diameters of currents ejected under different heads, but producing the same effect, are proportionate inversely to the velocities of ejection, divided by their fourth roots.*

This does not solve the problem before us, but emphasizes the difference between the problem of determining the diameters in the same supply-pipe at different elevations for permitting unimpeded flow, and the other problem of determining the size of ejectable currents producing the same power under different heads.

In the first specified problem sundry values are assumed as known or given, namely, the power required or obtain-

able, the quantity of ejection intended and the consequent transverse section and consequent diameter of ejectable current, as well as the main or maximum-head available or projected. The diameter $d$ of the area $F''$ of final ejection is in all cases as

$$\sqrt{F} \cdot \sqrt{4/p} = 1{\cdot}12838 \sqrt{F},$$

and by proper development it will be found that the diameter in inches is in all cases as:

$$d = \sqrt{P/v^3} \cdot \sqrt{2{\cdot}306916 \cdot 2g \cdot 4/p} = \sqrt{P/v^3} \cdot 13{\cdot}746 \text{ inches.}$$

While in prevailing practice it is assumed that this dimension $d$ must be increased about tenfold, in order to produce the force $P$, as it appears in the character of obtainable maximum effect, it is proposed in the new method that the values $P$ and $d$ as such be assumed as valid relatively, and the cause or necessity for increasing the value $d$ tenfold is intended to be removed, by harmonizing the dimensions of the supply-pipe, in its entire length, to the dimensions of the body of water, as it would assume them or successively modify them, were it to fall without hindrance or resistance, or to fall in such shape as nature, by the law of gravitation, would impart to such falling body of water, of which liquid body all parts are able to arrange themselves into the forms, as result from acceleration in their falling velocities, unless *resistance* to their natural (greater lengths ($v$) and smaller sections ($D^2 \cdot p/4$) arrangement will prevent them from obeying the law of nature.

In supply-pipes of uniform section throughout, such *resistance* is offered, unless their dimensions be excessive, and such *resistance retards the fall, reduces velocities or causes the effect commonly designated as loss of head, attributed to orifice of influx and to friction.*

It is the quantity, expressed in both volume and weight by $Q\ y$, which as a volume finds specific expression and description in the fundamental equations for force and work, by being there specified as an ejected column of the length $v$ per second, and of a constant transverse section $F$ (in units of 2·306916 square inches); and this quantity passes

any section-area per second. To remove all obstacle to the said quantity passing each section in its natural shape is the object of this research.

The assumption is, in approaching our problem, that the product $F \cdot v = Q\,y$ pounds of water per second be ejected, as a consequence of falling a distance $H = v^2/2\,g$. Nothing will be modified in this assumption by using $F''$, the expression for area of current-section in square inches, in place of using $F$, the expression of the same in units of 2·306916 square inches, because the equality between the two values is not destroyed in $2·306916 \cdot Q\,y = F'' \cdot v$, and because all further conclusions will be based on the fact that all different expressions used in substitution for $F \cdot v$ are equal to the third value $2·306916 \cdot Q\,y$.

The current-section $F'$ may then be expressed as of circular form by

$$F = d^2 \cdot \frac{4}{p}$$

and the fundamental equation then reads:

$$2·306916 \cdot Q\,y = F' \cdot v = d^2 \cdot \frac{p}{4} \cdot v = d^2 \cdot \frac{p}{4} \sqrt{H} \cdot \sqrt{2\,g}$$

The value $2·306916 \cdot Q\,y$ is assumed as immutable, as such, but the values that are equivalent thereto, as an entirety, are assumed to be products, the factors in which may be modified inversely to one another, leaving, nevertheless, the product unaltered. The factors that are subject to such modification are $v$, $H$ and $d$. It will be necessary to so designate these factors that each set of them, which, though singly different from one another, are conditional to the same product, give evidence in their expression that they belong to one another, and form a set in distinction of other sets. I therefore use $v$, $h$ and $d$,—$V$, $H$ and $D$,—$V'$, $H'$ and $D'$, and $V''$, $H''$ and $D''$ as such sets. And we may set down, as our fundamental condition, that an *equal quantity* (weight and volume) *pass* successively over distances of fall: $h$, $H$, $H'$ and $H''$ with different velocities $v$, $V$, $V'$ and $V''$, by reason of which variable velocity, at any given or selected point in such fall, the values $d$, $D$, $D'$ and

$D''$ must also be modified. And it is our problem to establish a law under which this modification takes place. The same line of surface or the level of the surface of the water supplying the pipe-line is assumed as in common to the different heads, or to the values $h$, $H$, $H'$ and $H''$.

$H''$ signifies 1 foot, and in consequence relates to a point in the course of the falling water, situate 1 foot below the surface of the inflowing water, a point which may be assumed as the orifice of influx of a pipe-line, though orifices at greater distances below the surface will also receive proper attention.

$h$ signifies the vertical distance of fall from the surface to the level of final ejection, with a velocity $v$ from a circular aperture of a diameter $d$. And $H$ and $H'$ relate to intermediate levels, that of $H$ being nearer to the level of final ejection than that of $H'$, or $h > H > H' > H''$.

The conditions, as assumed, may then be expressed by the equations

$$\frac{2\cdot306916\ Q\ y}{\sqrt{2g}\cdot p / 4} = d^2 \cdot \sqrt{h} = D^2 \cdot \sqrt{H} = D'^2 \cdot \sqrt{H'} = D''^2 \cdot \sqrt{H''}$$

As a consequence we have, relating to different levels in the supply-pipe, the heads above which different levels are the known values $H''$, $H'$, $H$ and $h$, in the order of successive fall, the following resulting equations:

$$d^2 = D^2 \cdot \sqrt{\frac{H}{h}} = D'^2 \cdot \sqrt{\frac{H'}{h}} = D''^2 \cdot \sqrt{\frac{H''}{h}} \text{ and}$$

$$d = D \cdot \sqrt[4]{\frac{H}{h}} = D' \cdot \sqrt[4]{\frac{H'}{h}} = D'' \cdot \sqrt[4]{\frac{H''}{h}} \text{ and}$$

$$D = d \sqrt[4]{\frac{h}{H}}$$

$$D' = d \cdot \sqrt[4]{\frac{h}{H'}}$$

$$D'' = d \cdot \sqrt[4]{\frac{h}{H''}}$$

As the value of $H''$ is specifically known as $H'' = 1$ foot, and as relating to an orifice of influx 1 foot below the surface of the supply water, the diameter $D''$ of such orifice must be by

$$\sqrt[4]{H''} = \sqrt[4]{1} = 1 \text{ as}$$

$$D'' = d \cdot \frac{\sqrt[4]{h}}{1} = d \cdot \sqrt[4]{h}$$

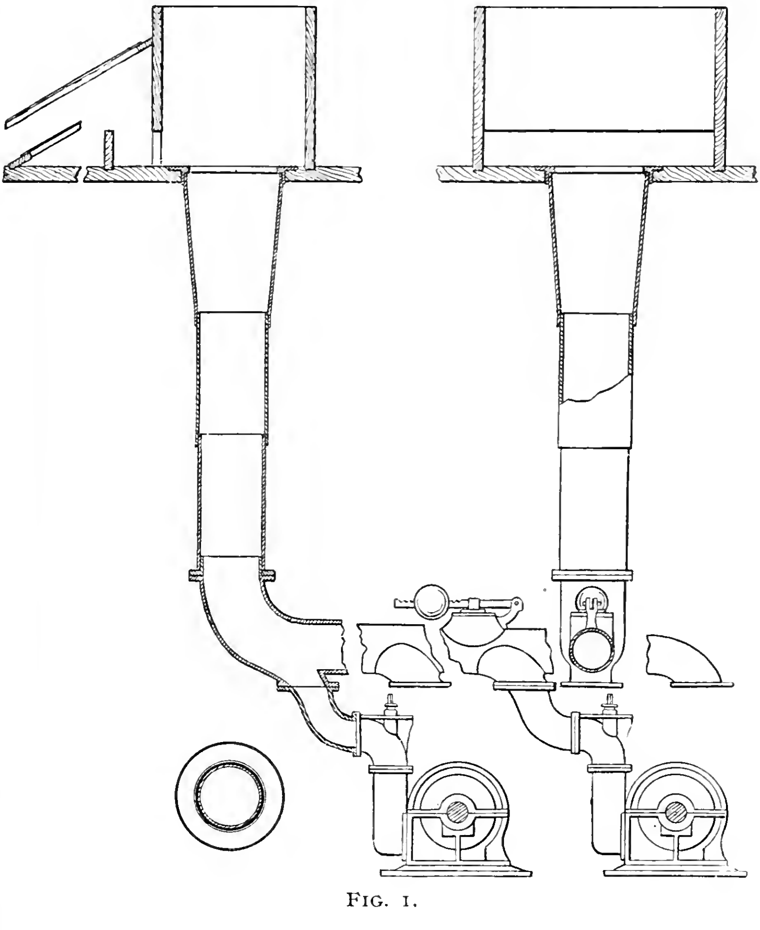


FIG. 1.

Assuming any other vertical distance $= H'$ between the surface of the supply water and the inlet of the supply-pipe, the required diameter of such lower inlet must be as

$$D' = \frac{\sqrt[4]{h}}{\sqrt[4]{H'}} \,.\, d$$

*Illustration:* Assuming final ejection to take place from a 2-inch pipe-end or nozzle, and the head of water, above the orifice, to be in one case $H'' = 1$ foot, and in another case $H' = 16$ feet, and in both cases the head, above the level of ejection, to be $h = 81$ feet—

We desire to ascertain the required diameter, in either case, of orifice of influx, to permit discharge under undiminished velocity. They are

$$D'' = d \,.\, \frac{\sqrt[4]{h}}{\sqrt[4]{H''}} = 2'' \,.\, \sqrt[4]{\frac{81}{1}} = 2'' \,.\, 3 = 6'' \text{ and}$$

$$D' = d \,.\, \frac{\sqrt[4]{h}}{\sqrt[4]{H'}} = 2'' \,.\, \sqrt[4]{\frac{81}{16}} = 2'' \,.\, 3/2 = 3''$$

The results show that a 2-inch pipe, ejecting under a head of 81 feet, will not eject with the velocity $v = \sqrt{h\,2\,g}$, unless it has an inlet, which, when 1 foot under water, is of 6 inches diameter, or, when 16 feet under water, a diameter of 3 inches.

If the orifice of 6 inches diameter is 1 foot under water, then the size of the supply-pipe, at 16 feet below surface of supply water, may be reduced to a 3-inch diameter.

Should in either of the cases, as stated, the engineer desire to ascertain at which level he may properly reduce the size of pipe to 2·5 inches, he will receive correct answer in using the equation as follows:

$$D = 2{\cdot}5'' = \frac{2'' \,.\, 3}{\sqrt[4]{H}} \text{ and } \sqrt[4]{H} = \frac{6}{2{\cdot}5} = 2{\cdot}4, \text{ and by}$$

$H = 2{\cdot}4^4 = 55{\cdot}296$ feet below the surface of the water-supply: the size of pipe may be reduced to 2·5 inches, without impeding the free flow of the ejectable maximum quantity of water.

(*To be Concluded.*)

# THE FRANKLIN INSTITUTE.



## A TRIP TO RUSSIA AND THE URAL MOUNTAINS.*

By George F. Kunz.

My remarks this evening will consist of a brief account of a trip made lately by myself to Southeastern Russia and the region of the Ural Mountains, a district renowned for its wealth of gold, platinum, iron, copper, chromite and precious stones. I shall confine myself, however, to a few points, such as the finding and working of precious or ornamental stones, the washing for gold and platinum, the casting of artistic iron work, and a few notes of general interest, not attempting a *résumé* of the mineral resources of this district, or the metallurgical processes, which have been fully described elsewhere by Humboldt, Rose, Murchison, Kokscharow, Ludwig, Karpinsky, Tscherneschew and a host of others.

It may safely be affirmed that few Americans have any conception of the immense extent of the resources of the Russian domain, or of the many and varied forms of industry and art which have been developed throughout its cities, towns and provinces. To some of these I shall allude briefly in this article, in connection with the mineral wealth of the Urals and the uses to which it is applied after its extraction from the earth. To obtain a more general idea of the arts and industries of this great empire, perhaps there is no work that a reader could consult with more advantage than the volume published in 1893 by the Imperial Commission in charge of the Russian Section of the World's Columbian Exposition at Chicago. This is one of the most full and able of the series of reports issued in connection with the great Fair, and though only entitled a "Catalogue of the Russian Section," it forms an octavo volume of more than 500 pages, and comprises over 1,000 titles of

* A lecture delivered before the Franklin Institute, April 20, 1898.

exhibits; while the notes in relation to a large number of them are of great value, historical, industrial and statistical.

Whoever contemplates a trip through Russia must be sure to secure a good passport. This should be *viséd* in Paris, or some European capital, before starting for Russia. From the questions put to me at these places, it soon became evident that no one of the Hebrew faith will be admitted into the realm of the Czar of all the Russias.

At the frontier the train stops for about two hours. Here, on the railroads, in the mines, on the steamers and elsewhere, I received the most courteous attention from officials and the Russians in all stations with whom I came in contact. They are exceedingly friendly to strangers.

To reach the Ural Mountains, one can go very comfortably by rail to St. Petersburg from Berlin, in thirty-two hours; or from Vienna in thirty-eight hours. From St. Petersburg the best train, leaving at eight o'clock in the evening, will take the traveler to Moscow, a distance of 366 miles, in fourteen hours, and from Moscow, 246 miles, in twelve and a half hours, to Nijni Novgorod, where, from the end of July to the middle of September, the great fair is held, at which at least $135,000,000 change hands every year in less than six weeks' time.

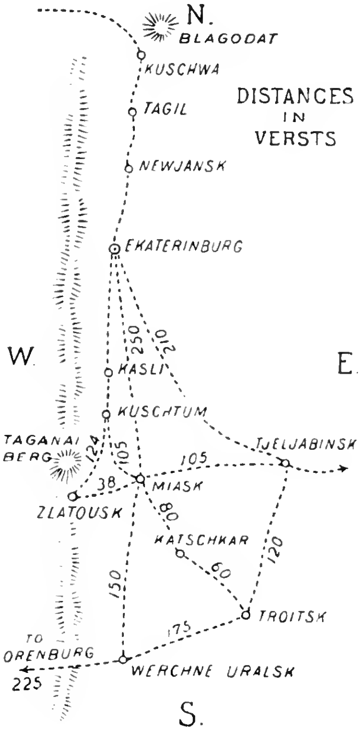
From Nijni Novgorod the traveler can usually reach the Urals by way of the various daily lines of steamboats that ply on the Volga and the Kama, 894 miles to Perm—a city of 30,000 inhabitants—in three and a half to four days. But in the time of low water in summer a week or more is frequently required.

From Perm one can go by the Ural Railroad, through the heart of the Ural to Tumen, the frontier of Siberia, a distance of 463 miles, in thirty-two hours.

Another route may be taken, however, in the dry season or winter, when the traveler can go direct from Moscow, by rail, to Zlatoust, a distance of 1,059 miles, in seventy-nine hours.

It will thus be seen that one may enter and cross the Urals by two routes, the northern one from Perm and the southern one by Orenburg. These two cities lie some dis-

tance west of the mountains, Perm in about latitude 58° north, or approximately on the parallel of the Hebrides, while Orenburg is in latitude 52°, corresponding nearly to that of London. The rich mining region of the Urals lies chiefly on the eastern or Asiatic side, between these two latitudes, at which the range is traversed by railroad routes: and the principal points to which I shall have occasion to refer lie along this eastern flank of the mountains, connected




by roads that run in a general way parallel to the range, *i. e.*, north and south. The principal city, Ekaterinburg, is well toward the northern part of this line.

The journey down the Volga and up its great affluent the Kama, is strikingly like a trip on our own Mississippi; the boats are comfortable, lighted by electricity, and the fuel used is petroleum, from the oil wells of Baku, on the Caspian Sea. If the traveler goes by way of Zlatoust, the

journey from there to Ekaterinburg, 171 miles northward, can be made by tarantas, in from twenty-four to thirty-six hours.

Russia has a population of about 110,000,000, of which the Ural region contains about 5,000,000; and the largest city in the Urals (Ekaterinburg) has 34,000 inhabitants.

The area of entire Russia is somewhat over 22,000,000 square kilometers, which is one-twenty-third that of the entire globe, or one-sixth of all its visible land; and exceeds by nearly five times the area of the United States, including Alaska.

In Russia there are only about 25,000 miles of railroad, while the United States has 184,428, or more than seven times as many miles—forty-five times as many for the area. The railroads in the United States employ 823,000 men, while those of Russia employ only 35,000.

On the other hand, the standing army of Russia consists of 835,780 men and 390,000 horses; while that of the United States had, prior to the recent war with Spain, 27,390 men.

These figures show that in each country about an equal number of men are employed in the armies and railroads together, but in reversed proportions; we may further note that the subsistence of the Russian army costs at least $50,000,000 annually, in addition to the armaments and fortifications; while the railroads of the United States made net earnings of $369,565,000 in the year 1897.

From these data we pass naturally to the next item, that of national debts.

The debt of Russia is $3,491,074,000; that of the United States is $1,700,961,695. This represents over one and a half times as much per capita in Russia as in the United States; although in the latter wage-workers earn from three to five times as much per day as in Russia.

In Russia there are ten rivers over 1,000 miles long, and five of these are over 2,000 miles long.

The valleys of the Irtisch and of the Kama Rivers, with the chain of the Ural Mountains as a connecting link, have been from time immemorial the natural route open to the Asiatic migrations, whose starting point was to the east of

Lake Baikal, and which gradually spread more and more widely on their way toward the Baltic Sea. Thus it is not surprising that the soil of these regions contains hidden archæological treasures in greater abundance than any of the central provinces of European Russia. To these we will refer later.

The river courses of Russia have done much to assist in the great migrations, and naturally guided or diverted them.

At Ekaterinburg, the heart of the Urals, starts the Great Siberian Street—the road to Siberia—one of the finest broad avenues in the world. The new Siberian railroad is to go direct from Zlatoust to Vladivostok on the Pacific, a distance of 4,000 miles.

As it is now, for half the year there is no connection between the Government of Perm (to which Ekaterinburg belongs), with its 2,500,000 inhabitants, and Moscow or St. Petersburg, except by the 170-mile journey by tarantas from Ekaterinburg to Zlatoust.

This gigantic enterprise of the Trans-Siberian railway will, when completed, be the longest railroad line in the world. It extends from the Urals somewhat south of east, passing around the southern extremity of the great Lake Baikal, which lies about midway between the Urals and the Pacific; thence a little north of east till it strikes the valley of the Amoor. Crossing this stream after some distance, it turns for about 300 miles directly south to the port of Vladivostok. Portions of the road are now under construction, especially those that by uniting the great river routes of Siberia and the connecting canals, will open partial communication as soon as possible throughout the great interior, which is now so inaccessible as to render its products of little value. It is not expected that the road will be finished before the year 1904; but several thousand miles are already laid, and parts of the route are in operation. At present, although gold is worked at many points throughout Siberia, yet the vast resources of the country in products no less valuable for use, but too bulky for easy transportation, such as coal, iron and the like, are unavailable. As

soon as the Trans-Siberian railroad is completed, these resources will be opened to the world, and also a vast amount of agricultural products which the country is capable of producing, but which are now unable to reach a market. The same is true of the stock-raising capacities of many parts of Siberia, and of the immense fishing industry that exists around Lake Baikal. On the shores of this great mid-Asiatic lake are no less than 400 fishing stations, giving employment to some 30,000 men.

As a consequence of the absence of railroads, the fact is noticeable that in all Russia the roads are generally good, and the facilities for wagon traveling are better than exist anywhere in the United States.

The traveling is all done, when not on the railroad or boat, by tarantas, especially on the government post roads. This vehicle, drawn by three running horses, is very comfortable, and one can average at least six to eight miles an hour, including the time required in the changes, which are made every twelve to eighteen miles, frequently going over ten miles an hour on the road. If the traveler contemplates a trip of some distance, or requires a long time, a good way is to buy a vehicle, put his baggage into it, and hire horses at the government post or other stations as he travels.

The Ural Mountains form the geographical dividing line between Europe and Asia. The average altitude of the entire chain is not over 2,000 feet; an elevation of 4,000 feet is exceedingly rare, and the highest peak (near Miask) in the entire range is 5,540 feet.

The chain runs north almost in a direct line from its southern point near the Aral Sea, in latitude 46 north to latitude 65 north, then deflects to the east as far as north latitude 67, and runs to the Arctic Ocean.

The average width of the range is scarcely forty miles—only in rare instances does it attain a width of 100 miles. The entire range is embraced in the Governments of Tobolsk, Perm and Orenburg.

The various inhabitants of the Ural district are as follows: In the northern part, in the Government of Perm, with 2,700,000 inhabitants, are what are called the Great

Russians; south of this, in the Government of Orenburg, with a population of 1,300,000, there is a tract of land inhabited by the Bashkirs, a Mohammedan sect, who live in villages, and are an industrious, peaceful people. South of and bordering on these, for the purpose of keeping peace between the other peoples just named, and also for maintaining the power of the Czars, are the famous Cossacks, who separate the Bashkirs from the Khirges, and interspersed through here are also Tartars.

The Khirges are a rude, nomadic people, who raise immense herds of cattle, sheep and horses, which they sell or trade to the inhabitants of Perm, Orenburg and the Volga district.

There has just appeared a work of great value relating to the geology and mineralogy of the Ural region, viz.: the collection of guide-books prepared by the Russian committee for the series of scientific excursions in connection with the seventh meeting of the International Geological Congress, which was held during the past summer in St. Petersburg.* This volume consists of thirty-four monographs by leading Russian geologists, treating of the different portions of country to be visited or traversed by these excursion parties. These papers are accompanied by maps, illustrations, bibliographies, etc., and have been prepared with the utmost care and pains, and strictly brought up to date in their accounts. Five of these monographs relate to the mining region of the Eastern Urals—the same that was visited by the present writer.

This remarkable and indeed monumental work is one that reflects great honor upon the geologists who prepared its various parts, and it shows very strikingly the liberal and princely manner in which the Government and the scientific men of Russia plan and carry out such courtesies. The whole forms an octavo of over 500 pages, beautifully printed, and bound in a spring cover, so that each local

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* Guide des Excursions du VII Congress Géologique International, avec 39 planches, nombreuses figures, cartes locales et une carte géologique de la Russie d'Europe a l'echelle de 1:300,000. St. Petersburg: 1897. Imprimerie de M. Stassulewitsch, Wassili Ostrow 5, ligne 28.

monograph could be taken out and used separately during the portion of the journey with which it is concerned. The translation, chiefly into French and in some cases into German, is excellent; and the whole is a noble gift to the geologists from other lands who attended the Congress.

These excursions, which were planned to visit all the districts of Russia most interesting to the mineralogist and geologist, were arranged on a scale truly imperial in liberality. By special order of the Czar, all the members who took part were provided with first-class transportation, free of expense, over the railroad and steamer routes selected, to points as distant as the Eastern Urals, the Caucasus, the Crimea, the oil deposits of the Black and Caspian Seas, etc. An example of the faithfulness with which this pledge was carried out, may be cited in the following instance: It was found at a late date in the arrangements, that there were no first-class cars on the road between Tiflis and Batoum on the Black Sea, over which one of the parties was to travel; and the Government immediately sent five cars to that remote section, at a cost of $600 each, solely for the use of the excursion.

In speaking of the mines of the Ural Mountains, it is well to observe that this term is employed in a very general sense, somewhat as the name Alleghany is with us. The Urals, in fact, comprise several ranges, of which the easternmost is the one specially referred to here. This eastern range is frequently designated as the Ilmen Mountains, though, in fact, this term is rather too limited. The richest mining districts are indeed in the Ilmen Mountains; but the same line of elevations, geologically and geographically, continues, with some interruptions and under various local names, for a long way parallel to the main Urals at a distance of from twenty to forty miles east. In a general way, therefore, it holds somewhat the same relation to the Urals proper, as the Blue Ridge does to the main line of the Alleghanies, and in the same manner bears different names in different parts of its course.

The principal rocks of the Ural region are metamorphic-

chloritic and talcose schists, serpentine, quartzite, coarse granite, gneiss, limestone and dolomite.

The mineral statistics for 1892 show that, as compared with Russia, the United States produces ten times the pig-iron, twenty-three times as much coal, twenty-three times as much copper, fifty times as much silver, six times as much quicksilver, 200 times as much lead and five-sevenths as much petroleum; whereas Russia produces nearly all the platinum and three times as much manganese; also, three-fourths as much gold.

A brief history of the origin of the greatest mining estate in the Urals, Nijni Tagilsk, may prove interesting.

When Peter the Great visited Tula in 1710, he brought with him a revolver which had been presented to him by an English nobleman.

This having gotten out of order, he inquired of the Governor of Tula if he had any one among his many skilled metal workers—for which the Government of Tula has always been noted—who could repair it.

The Governor immediately replied that one Demidoff, a young smith, undoubtedly possessed the requisite skill. Demidoff was then called, and assured the Emperor that he could put the revolver in perfect order. Peter the Great left it with him, and came again in about ten months. Demidoff handed him a revolver, which he, the Czar, examined carefully and seemed pleased with it, and complimented him on the good repair. He then showed him another one which was not quite as good; but this was the original one, he having made a new weapon better than the old. His expertness pleased the Czar, who then gave him and his heirs Nijni Tagilsk as long as it should be used as a mining estate.

Demidoff struck roads through an impenetrable forest, so true in direction and location, that all attempts to make better lines have failed, and his original roads are used to this day.

So expert was Demidoff as a smith that it is commonly said that he was able to put hoofs on, and had harnessed, a pair of fleas.

The celebrated mining locality of Nijni Tagilsk com-

prises really several separate mines. There are in the first place, six important mines of magnetic iron ore, which surround and penetrate the famous iron mountain, known as Mount Wyssokaia (or in Russian, Wissokaiagora), a somewhat isolated hill of porphyry 2,000 feet long, 1,500 feet wide, and 250 feet high. Of these mines, Nijni Tagilsk is the first and the most noted, the six together dividing up the approximately circular hill in something like irregular sectors. The ore taken out is used in the great iron works of the adjacent town of Tagil, which were founded by the original head of the Demidoff family, just now referred to. A little distance southward, close to the base of the mountain, is the celebrated copper mine of Mednoroudiansk, from which nearly all the malachite used in the world has come, a circumstance that has made this locality famous. It is unfortunate that the name Nijni Tagilsk, which really belongs to the adjacent iron mine, should have become so identified with the malachite, in mineralogical books and collections, that the error can probably never be corrected. The occurrence of the ores is peculiar and interesting; the iron is in beds and seams closely involved among the porphyritic rocks, in such a manner that Professor Tschernitschew, the eminent authority who has described these mines for the recent Congress of Geologists, regards them as of simultaneous formation with the igneous rocks in which they occur. The copper mine forms an ellipse 1,800 feet long and 290 feet broad, and the ores occur in ferruginous clay, apparently formed by an alteration of beds of tufa or breccia derived from the porphyries and other adjacent rocks, and included between upturned beds of Devonian limestone.

In 1835, an enormous mass of malachite was struck in mining at Nijni Tagilsk, at a depth of over 200 feet, and beneath the bed of a small stream, known as the Roudianka. This great mass or block, when disengaged from the surrounding rock, measured some 17 feet by 8, with a thickness sloping from about 6 feet at one end to a little over 1 foot at the other. Its total weight, including portions cut off in extricating it, was estimated at 65,000 kilograms. The block was surrounded and partly penetrated

by iron and manganese ores; but large portions of it were compact malachite, of reniform structure, beautifully varied with light and dark green. The inflow of water rendered it difficult to determine what lay below the mass; but it was thought that perhaps this was only the upper portion of a more extensive body of malachite. The largest mass previously found was in the Gournichef mine, and weighed 1,789 kilograms.

The copper deposit at this locality is attached to the magnetic iron mountain Labaschka, which is 3,000 feet long, 1,000 feet wide and 100 feet high. The Wissokaiagora is covered to a depth of 30 feet with loam—the upper layer is reniform limonite, then other forms of limonite, coarsely and finely granular, gradually changing into a compact magnetite, flanked on one side with compact crystalline limestone, containing silurian fossils, notably *pentamerus*, and on the other side with diabase.

The magnetite of the Labaschka is so highly magnetic, that all the tools brought in contact with it change to magnets. No ore poorer than 60 per cent. of iron is ever used, or any that is at all impure. From this ore is made the famous Russian sheet-iron, and there is enough in sight here for a hundred years to come.

A little farther to the northeast of Wyssokaia is another and loftier hill, belonging to the Government, known as Mount Blagodat. Here again occur extensive mines of magnetic iron, associated in the same intimate manner with masses of porphyritic rock, which have been forced out among limestones of Lower Devonian age.

*On the entire estate of Nijni Tagilsk (30,000 inhabitants) and Neviansk Savod (16,000) there is not a single mile of railroad. Everything is hauled by horses; and when one inquires why, he is informed that the mines were granted to the original Demidoff, on the condition that he should employ every person in the entire domain. Hence the

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* I must also express my sincere thanks to Prince Demidoff, who, in response to the letters that I had to him, arranged that his engineers, Grammatakoff and Hamilton, not only afforded me every opportunity, but the horses and men to guide me over this marvelous and unique estate.

caravans, which consist of from five to forty wagons in summer, or sleds in winter, are constantly seen crawling along the roads to the railroads. Strange to say, a rigid eight-hour law exists in the Urals. No one is allowed to employ a man more than eight hours for a day's labor. It is customary for them to begin work at six in the morning and to stop at six in the evening. One hour is allowed for breakfast, from eight to nine; two hours for dinner, from twelve to two, and one hour for supper, from four to five.

The results accomplished with primitive appliances are in striking contrast to the modern methods used in the United States, notably in Minnesota, where in one day 4,000 tons of ore are raised by one steam-shovel, railroaded to lake docks and sold over 1,100 miles distant at a profit of $2.85 a ton.

An interesting social custom at Nijni Tagilsk is, that many of the people use visiting cards, made at the Demidoff works, out of Russian sheet-iron; this rolled to the thinness of paper, is even more flexible than a thin plate of mica.

The auriferous deposits of the Urals are, as usual, of two kinds, which have been called by Karpinsky primary and secondary. In the former, gold is found either in quartzose vein-stuff, or interspersed through the mass of crystalline rocks, such as diorite and serpentine; while the secondary deposits are auriferous sands, either immediately overlying the primitive deposits, or transported and re-arranged at some distance from the point of origin.

The primary gold deposits of the Urals are very numerous, four groups of them being actually worked, namely, those of Berezowsk and Gora Blagodat, those of the district of Miask, those of the Bashkir territory and in that of the Orenburg Cossacks.

The Berezowsk deposits, which are the only ones that have been systematically developed to any extent, are included in an area of about twenty-two square miles, in which the prevailing rocks are schists penetrated by numerous veins or dykes of a fine-grained granitic rock containing pyrites and known as beresite, which vary in thickness from

3 meters to 40 and upward, and in many cases extend beyond the limits of the mining region. These beresite dykes are traversed by numerous fissures filled with quartz, forming veins varying in thickness from about 10 to 70 millimeters, or on an average 30 millimeters, having a general east and west course, often uniting into groups. but never becoming parallel to the enclosing dyke. Sometimes, but rarely, they pass from the beresite into the neighboring schistose rocks. The vein-stuff as well as the rock, where most auriferous, is rusted from the decomposition of the pyrites. The best mines yield from 1 to 1¼ ounces per ton, 10 grams (about 7 pennyweights) being considered the lowest workable limit. The pyrite is often much richer than the quartz, in some instances averaging up to 6 or 7 ounces per ton. Below the level of decomposition of the pyrites into gossan, or, as they are locally called, krassiks, the gold appears to be entirely contained in the sulphides.

The secondary auriferous deposits, although called sands, are almost entirely clays, pure or somewhat sandy, and enclosing rolled masses and blocks of many different rocks. They are found throughout the whole Ural region, over a length of more than 500 miles, filling the valleys and forming marshy plains on both slopes of the chain, the larger development, however, being on the eastern side. They form placers of elongated shape, closely conforming to the course of the valleys and ravines in which they occur, and evidently but little removed from the rocks whence they have been derived. In many cases they have not been transported at all, but are merely the decomposed and washed surface portion of auriferous veins beneath; and the gold-bearing sands can be traced almost directly downward into crumbling gold quartz. At other times they have been transported somewhat, and the gold is richest in a band or line which seems to mark the course of the strongest part of the current. Where there are outcrops crossing the bed, or where the surface (as usually when it is limestone) is irregularly worn or fissured, there the gold accumulates as by a natural riffling process, and the beds are exceptionally rich. From this circumstance has arisen an

idea that the placers are richest where the rock is limestone; but this is only accidental, and the actual richness depends mainly upon the immediate proximity of the greenstone and talcose and chloritic schists in which the veins occur.

The placer deposits are believed to be very local, and geologically very late; they are all post-tertiary, some of them even recent. The older ones contain remains of quaternary animals, such as rhinoceros and mammoth, the later ones in some cases have yielded objects of human handiwork.

The auriferous beds or placers vary in thickness from about $1\frac{1}{2}$ to $3\frac{1}{2}$ feet, in breadth from 60 or 150 feet, and exceptionally 300 feet, and in length from 60 or 80 feet to 1,500, the direction being generally parallel to that of the chain. The most extensive deposits are those of Balbuk, $2\frac{3}{4}$ miles long, and Stolbuk, $3\frac{3}{4}$ miles. The sterile covering or overlying layer is usually less than 13 feet thick, although exceptional deposits have been found at 60 and even 130 feet below the surface. The overlying mass very frequently contains peat bogs. The amount of gold found varies from 12 to 39 grains per ton of sand, although occasionally it is double or even four times the latter amount.

The gold varies much in size, as usually in such deposits. The largest nugget obtained, from the Tzarévo-Alexandrovsky placer, near Miask, weighed 36 kilograms.

In the Kotchkar district placer mining dates from 1844, on the small rivers known as the Kaminka and Sanarka. These beds yielded also valuable gems, topaz, beryl, amethyst, euclase, ruby, etc., and became celebrated therefor. After some twenty years or more the yield of gold began to diminish, and vein mining was taken up. This has now become the principal method of exploitation since about 1868, and the placers are quite subordinate. The annual yield in the Kotchkar district is now about 1,600 to 1,800 kilograms of gold, of which the vein-working furnishes 1,300 to 1,400. The total production in the district since 1844 to the present year is stated to be about 47,000 kilograms, of which 25,000 have come from the placers and 22,000 from the rock.

Not only in the region just mentioned, but widely throughout the Urals, many minerals are found with the gold in these alluvial deposits, especially magnetic iron sand, with ilmenite and chromite, much garnet, also zircon, beryl and other gems, occasionally diamonds, though none of any consequence, and platinum, of great importance. Diamonds are also found in gold placers on the west side of the Urals, in the valley of the Poloudenka River and its tributary, the Adolphe, at a point somewhat north of the Ural railroad, some 240 miles east of the city of Perm.

The platinum of the Urals is nearly all found on the eastern side of the range. It has not yet been obtained commercially except in alluvial deposits, in which it is always associated with gold. Sometimes the latter predominates, and the platinum may not exceed 1 per cent. of the product of gold; while, on the other hand, gold may be almost absent; and the deposits in which this condition prevails, although less abundant, are those of most value.

These are confined to the districts of Nijni Tagilsk, Gora Blagodat and Biseik. The first of these localities extends for about twenty-five miles to the south of the village; and judging from the associated minerals, such as olivine and chromite, the deposits appear to be derived from the débris of a mass of serpentine known as Mount Solvaiska or the White Mountain. The platinum is found in grains and nuggets; the largest of the latter known, weighing about 320 ounces, is in the Imperial Museum at Vienna. The yield varies from 39 to 195 grains per ton. The richest deposits, those of the Martian River, are from 13 to 16 feet thick, and are covered by 60 to 70 feet of overlying material, chiefly clay. The conditions of occurrence in the other localities are similar, except at Gora Blagodat, where the bed-rock of the alluvium is limestone, but outcrops of porphyry and serpentine are found in the vicinity.

In the platinum sands and gravels are occasionally found masses of the metal associated with and occurring in chromite; and as in the platinum gravels serpentine is always found associated with an abundance of chromite, it seems

evident that the source of the platinum must be in serpentine, originally a peridotite.

The first discovery of this metal in the Urals was made in 1824, and from that time till now, the richest yield has been along the valleys of the Martian and Tchaouch Rivers, and of the River Isa, in the neighboring district of Nijni Tourinsk. Thus far it has only been mined from the placers, but the theoretical conclusion previously referred to, that its source is really in the serpentine rocks, which had come to be generally adopted of late by the Russian geologists, has now been fully established. The first actual discovery of platinum in the rock was made accidentally in 1892, bv a workman, in the Martian River district. The locality was subsequently examined and reported upon by Professor Inostranzew, with full confirmation of the occurrence of platinum *in situ* in the serpentine.

This rock, however, is itself a secondary one, resulting from the alteration of others, usually of the massive eruptive rock, termed peridotite, which occurs largely in this eastern part of the Ural system. Professor Tschernitschew, in a recent memoir on the region, traces all the serpentines of the Urals to the alteration of peridotites and diallage rocks, and holds that this process was accompanied with the separation of the chromic-iron, which plays so important a part in many of the serpentines, both there and elsewhere, and with the precipitation throughout the rock of both platinum and gold.

The gold deposits are partly the property of the crown or its lessees, and partly of private individuals; but in the latter case there is often a reservation of minerals which are subjected to royal rents. The rate paid by the crown lessees is from 8½ to 20 per cent., in addition to which a 3 per cent. tax is levied on all gold produced in any of the mines, the entire output being compulsorily salable to the Government.

The whole gold product of the Urals and Siberia is sent to the imperial assay office at Ekaterinburg, where it is melted and cast into bars, the assay of which forms the basis of final settlement between the Government and the miners.

Platinum working, on the contrary, is free from all taxation, and as the Government monopoly of refining, which was kept up for a time, has been abandoned, the product is mostly placed on the London and Paris markets, and there controlled by one or two individuals.

In working the alluvial gold deposits, two methods are followed. In the first, the plant and apparatus are provided by the ground owner, who hires labor and directs the operations either personally or by deputy; while in the second, a system of tribute is followed, the ground being let to free laborers or starateli, who provide everything necessary for working, and deliver the product at a fixed rate to the proprietor. This price may vary, according to the difficulty of working, from $9 to $10.50 per ounce; but in all cases the prime cost in the proprietary workings is higher than in those of the free laborers, who are able to handle, with a profit, material with but from 8 to 10 grains of gold per ton. Platinum sands are considered poor when containing less than 45 grains of the metal per ton, and rich when above 180 grains. The lowest profitable limit seems to be about 39 grains.

*The platinum workings of Avorinski are at present the most important of that class. The deposits, from 13 to 16 feet thick, lie upon a conglomerate of serpentine, and are covered by nearly 80 feet of barren material; they extend for about one-and-a-half miles, with a breadth varying from 70 to 250 feet.

At Avorinski the average yield is about 87 grains of platinum minerals per ton; but in places it goes up to twenty, thirty or even fifty times as much. The working is entirely subterranean, but open, small pits 70 to 80 feet apart being sunk to the deposit, and the material, drawn to the surface by windlasses, is washed in the ordinary Siberian frame at the mouth of the pit. About 400 hands are employed, the work going on night and day.

The crude platinum contains about 1 part in 4,000 of

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*The illustrations taken at the time by the author are reproduced in the volume on Mining, 11th U. S. Census, 1890.

gold, which is separated by amalgamation and washing with water in large capsules. The final product contains 90 per cent. of platinum.

Besides the platinum found from Gora Blagodat, not far from the Isa River, to Nijni Tagilsk, a distance of over fifty miles, it occurs also near Miask, more than 100 miles further south. But here, only about 1,200 ounces are obtained annually, while the yield of the entire Urals is about 55,000 ounces.

The platinum district of Isa River and its tributaries is worked by the Government, and by a number of private owners jointly with the Government. The platinum is whiter than that of any other district; whereas that from the Demidoff estate in the Martian Range, farther south, has always a rusty appearance.

PRICES PAID FOR PLATINUM WIRE.

| | Per Ounce. |
|---|---|
| 1883 | $7 35 |
| 1884 | 7 80 |
| 1885 | 7 75 |
| 1886 | |
| 1887 | 7 80 |
| 1888 | 7 65 |
| 1889 | 8 50 |
| 1890 | 12 95 |
| August, 1890 | 17 00 |
| December, 1890 | 17 00 |
| January, 1891 | 16 85 |
| February and March, 1891 | 14 00 |
| April and May, 1891 | 13 00 |
| June, 1891 | 12 00 |
| August, 1891 | 12 50 |
| September, 1891 | 11 00 |
| October, 1891 | 10 20 |
| November, 1891 | 9 80 |
| December, 1891 | 9 40 |
| December, 1894 | 11 00 |
| May, 1895 | 10 40 |
| May, 1896 | 12 40 |
| May, 1897 | 14 00 |
| July, 1898 | 14 40 |

Leaving now the mining of the precious metals, we turn to the iron industry of the Urals, which presents some feat-

ures of special interest. We have already noted the smallness of the iron product of Russia as compared with that of our own country; and the reason of it, also, as largely due to lack of transportation facilities. But the Russian iron-work has great importance notwithstanding, and is well deserving of attention.

At Zlatoust, formerly the terminus of the Orenburg Railroad, in the very heart of the Urals, there is a Government armory, where many of the firearms, swords and other weapons used in the Russian army are made. In addition to the arms, some remarkable specimens of cisselier or chisel work, repoussé work and etching of iron and steel are executed here in great perfection, principally in the ornamentation of table knives, daggers, swords and quaint oriental weapons. This etching and ornamenting of iron-work is also done by a number of local masters throughout the district. Some remarkable examples were presented to Sir Roderick Murchison, and are on exhibition now in the Royal School of Mines in London.

From these armory works at Zlatoust there was sent to the Columbian Exposition at Chicago a remarkable display of iron and steel products, comprising over 150 articles illustrating the skill and taste of the Russian ironworkers. Among these were weapons of all kinds—swords, sabres, hunting knives, etc.—some forged, others cast, many damasked, all elegantly ornamented and mounted; then a series of table knives and fruit knives, the blades decorated with designs in blue or gold, fruit knives gilded, nickel-plated, etc., the handles of wild-goat's-horn, ivory, ebony, malachite, jasper, all elaborately wrought and ornamented, and a number of miscellaneous articles of *vertu*, all designed and manufactured at this remote spot, the very name of which is scarcely known to most of our people.

At Kasli, 130 versts south of Ekaterinburg, and about the same distance north of Zlatoust, are situated the Kasli Iron Works, remarkable for their fine artistic castings.

It may be of interest to mention that these Kasli Iron Works daily cast kettles, or gypsy or caravan cook pots, to the extent of 32,400 pounds. These are of remarkable thin-

ness, weighing less than 30 pounds each, although more than 3 feet in diameter. They also make lavabos, or laving dishes, used by the Mohammedans in their religious ablutions, which they are supposed to perform every day. These are hauled by horses to Troitzk, about 150 miles, where they are purchased by the Khirghes, Persians, Turkomans, natives of Siberia and other oriental countries, who carry them away on camels, and who use up the product of these works, amounting to 550 tons a year.

The engineer, Karpinsky, whom I had the pleasure of meeting after visiting the works, had the courtesy and generosity to present our United States National Museum with a large series of these articles.

At Troitzk, in Orenburg, in the steppes east of the Urals, a great fair is held every May, when thousands of camels are brought to that city (which is the beginning of the Orient in every sense of the word) bringing Eastern products and returning loaded with these pots. Camels with one hump carry two loads of ten poods each—720 pounds. These camels sell as high as $125, whereas a camel with two humps, which is only able to carry one load of ten poods—360 pounds—sells for only $60 to $75.

An important economic mineral of this region is chrysotile, a fibrous serpentine, often called asbestos, and sold as such. It is extensively worked near Baschenova, twenty miles off the Siberian road, near the old emerald mines. Over 1,000 men and women are employed here, who generally come some distance from the surrounding country, and must obtain leave of absence from the chief of police of their district—their papers requiring a number of revisions during a year—as unrestricted migration is not permitted in Russia. The working is all done by stripping the serpentine in layers of 4 to 5 feet deep.

While visiting the Petrokamenski Savod, Government of Perm, my attention was called to a new discovery of chrysotile on the Wuoluij River, seven or eight miles west of Petrokamenski Savod, which is likely to be of great importance. It is found loose in the soil, as well as attached to the serpentine. Part of the material found here consists

of masses in which the fibres are over five inches in length, of remarkable purity and strength. From the fact that this locality is at so great a distance, 120 miles, from Baschenova, there is every reason to believe that this useful industrial mineral, which is commercially used for many of the purposes of asbestos, may exist in large quantities in the Ural Mountains.

In 1891, in the Revdat district of Revdenski, a series of nickel ores occurring in serpentine was found, resembling in many respects the minerals found at Riddle, Douglas County, Ore. To one of these dubious silicates the name of Karatskoffite has been given.

Immense tracts of peat or turf exist throughout the Urals. Should the use of this become general, an opportunity would be afforded for the regrowth of the forests for which this region was so remarkable less than half a century ago. Wherever the original growth of pine has been removed, the second growth is always one of birch, the bark of which is extensively used throughout the Urals for milk-pails and other utensils. The peasants have also begun to use turf instead of wood as fuel; and the Syssersk Iron Works began to use it only a few years ago, for the smelting of iron. These turf deposits were described and their extent remarked on by Ludwig, as early as 1846.

In addition to the cutting down of the forests for fuel, may be mentioned the ravages made on these pine woods by a bombycid moth (*Bombyx piniperda*). For a distance of over three miles a little south from Vavlamova, Government of Perm, these insects have killed every pine tree on both sides of the road. Strange to say, the birch trees are not injured, but every pine has been destroyed, with the exception of a few trees that were isolated in a group of birches, suggesting that a border of birch trees would prevent the ravages of this destructive insect.

About nineteen-twentieths of all the buildings in Russia are of wood, and these are entirely destroyed by fire once in fourteen years. These fires are often very disastrous. In May, 1890, for example, a fire at Neviansk Savod destroyed 1,800 houses, and thirty-eight persons lost their lives, either

by fire or by drowning in the lake whither they were driven by the flames. In June of the same year, at Kanova, a village ten miles from Neviansk, more than fifty houses were destroyed.

In the south of Orenburg, in the Bashkir country, where trees are scarce, one can always be sure that a wood or grove marks the site of a graveyard, in which, if uninformed, one might camp for a day without knowing what it really was, as only an angular stone, from 1 to 3 feet high, is placed on the spot to mark a grave. These rocks project in all positions, and rarely, if ever, does one of them bear an inscription.

My friend, Mr. H. Templeton Ellicott, an English mining engineer, who had rendered the Bashkirs many services and won their favor, was offered the highest honor that a Bashkir can offer a Christian—the privilege of having his body interred in a Bashkir graveyard at his death. Mr. Ellicott, up to the present time, has not accepted the honor.

South of the Bashkir country and near Kushva, in a district over ten miles long, an immense amount of mining for gold is carried on, frequently in a very primitive manner, by the peasants, who either work alone or have a very small force of men digging out the alluvial gravel from a depth of 6 to 20 feet.

I was especially struck with the curious homes of these people. The entrance to some was below the surface of the ground, the roof projecting only from 2 to 4 feet above the ground, the small window running from the ground to the roof, and the steps going down inside of the house.

[*To be concluded.*]

# MECHANICS OF THE CAMBERED BRAKE-BEAM.

BY IRVING P. CHURCH, C.E., ITHACA, N. Y.

By "brake-beam," in this paper, will be understood the *trussed* beam shown in diagrammatic form in *Fig. 3*, consisting of a prismatic bar or beam $AOB$, a short post or strut, $OD$, and two prismatic tie-rods or tension-members, $GD$ and $G'D$, meeting the post at the joint $D$. By "cambering" this brake-beam is meant forcing together the extremities $B$ and $G$ (and $A$ and $G'$) until they meet, and permanently fastening them in this position. In the assumption of this constrained form the elastic limit is not supposed to be passed in any member. This constrained or "cambered" form is shown by the full continuous lines in *Fig. 4*, in which the vertical dimensions of the whole frame, and the amount of bending of the bar $AOB$, are much exaggerated.

This state of initial constraint, brought about before the brake-beam is put to use, occasions a certain initial tensile force ($T_0$) in each of the tie-rods, and a thrust ($Q_0$) in the post, and subjects the bar $AB$ to combined flexure and thrust. It is the object of this paper to determine the stresses induced in the various members of the brake-beam when employed in pressing the brake-shoes at its extremities against the car wheels; and also the deflection of the middle point, $C$, at the same instant.

As preliminary to the final object, it will be necessary to recall certain relations between the various quantities concerned in the case of an elastic prismatic bar of homogeneous material under combined flexure and thrust, as shown in *Fig. 1*. Let the length of the bar (originally straight) be $2\,l$, and let it be pressed against a single support $B$, at the middle, by two oblique equal forces, $P$ and $P$, applied at the extremities $O$ and $O'$, at equal angles $\alpha$ with the tangent line drawn at $B$ to the elastic curve thus produced. Let the sectional area be $F$ square inches, the modulus of elasticity of the material $E$ pounds per square inch, and the moment

of inertia of the cross-section $I$ (referred to an axis containing its center of gravity and perpendicular to the plane of flexure), and $Q$ pounds the reaction of the support.

$$\text{Evidently } Q = 2\, P \sin.\, \alpha \tag{1}$$

According to the ordinary and well-known theory, the bar will be shortened by an amount

$$2\, c, \text{ where } c = \frac{(P \cos.\, \alpha)\, l}{F\, E} \tag{2}$$

while the deflection $d$ (see figure), unless the angle $\alpha$ is very small, is given by the formula

$$d = \frac{(P \sin.\, \alpha)\, l^3}{3\, E\, I} \tag{3}$$

We note in the figure that the right-hand extremity of the bar has been displaced a distance $c$ longitudinally, and a distance $d$ laterally, from its original position $A$. A similar statement, holds, of course, for the other extremity.

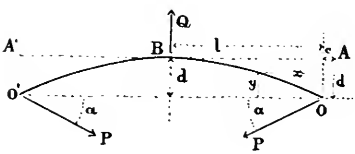


FIG. 1.

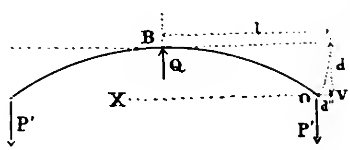


FIG. 2.

[NOTE A.—It will doubtless be of interest to mention more exact relations in connection with the bar in *Fig. 1*, for the benefit of those who would like to follow up the matter with greater theoretical accuracy.

A more exact expression for the deflection $d$ can be obtained by treating the elastic curve $O\, B$ according to a method similar to that outlined on p. 545 of Professor Bovey's "Theory of Structures," for an obliquely loaded and bracketed column; that is, by writing the bending moment, or "moment of stress-couple," at any section $= (P \sin.\, \alpha)\, x + (P \cos.\, \alpha)\, y$, instead of $(P \sin.\, \alpha)\, x$.

This leads finally to the form

$$d = (\tan.\, \alpha) \left[ \sqrt{\frac{E\, I}{P \cos.\, \alpha}} \,.\, \tan. \left( l \sqrt{\frac{P \cos.\, \alpha}{E\, I}} \right) - l \right] \tag{3a}$$

Incidentally, it may be remarked that if the angle $\alpha$ were zero, the deflection $d$ would also be zero, *unless*

$$tan \left( l \sqrt{\frac{P}{E\ I}} \right)$$

*were infinite*, in which case $d$ would be indeterminate, but

$$l \sqrt{\frac{P}{E\ I}}$$

would have to be

$$= \frac{1}{2}\pi, \text{ or } \frac{3}{2}\pi, \text{ or } \frac{5}{2}\pi, \text{ etc.}$$

In other words, we are led to Euler's formula for a slender column.

(If $\alpha$ were greater than 90°, we should have the case of combined flexure and tension treated on pp. 356, etc., of the writer's "Mechanics of Engineering." This case is also given by Prof. James MacMahon, in his chapter on "Hyperbolic Functions," in Merriman and Woodward's "Higher Mathematics." The result for the deflection in this latter treatment (p. 152) is very nearly the same in form as in Equation (3a) above, but contains, instead of

$$tan. \left( l \sqrt{\frac{P\ cos.\ \alpha}{E\ I}} \right)$$

the hyperbolic tangent of

$$\left( l \sqrt{\frac{P\ cos.\ (\pi - \alpha)}{E\ I}} \right)$$

where $\alpha$ still refers to *Fig. 1* of this paper, but is greater than 90°.)

Besides the longitudinal shortening $2\ c.$ of the bar, as due to the thrust component $P\ cos.\ \alpha$, we ought more strictly to consider what might be called a "longitudinal deflection," as illustrated in *Fig. 2*, where a case of pure flexure is shown, the forces $P'$ and $P'$ being perpendicular to the bar. The extremity of the bar having been displaced from $O'$ to $O$ during the gradual increase of the force $P'$ from a zero value, $O'B$ being tangent to the elastic curve at $B$, the middle of bar, we note on drawing $O'\ V$ perpendicu-

lar to $O'B$ that a displacement $O'V$ of the extremity has occurred in the direction of the length of the bar, and this we may call a "longitudinal deflection" of extremity, due to the curvature of $BO$, and not to thrust. The value of this distance $O'V$, $= d''$, can be obtained by a consideration and application of the properties of a curved beam or elastic arch, and is

$$d'' = \frac{1}{15} \cdot \frac{P'^2\, l^5}{E^2\, I^2} \tag{3b}$$

To avoid complexity in what follows, the stricter relations mentioned in this note will not be observed. The effect of shearing stresses in influencing deflection will also be neglected.]

To determine the initial stresses in the brake-beam, *i. e.*, those due to camber, let us consider *Fig. 3*, which shows in

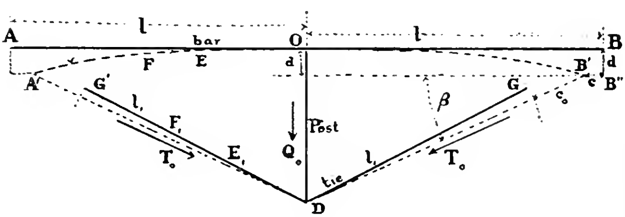


FIG. 3.

full continuous lines the bar, the post, and the two tie-rods, *under no strain.* For the bar, let the sectional area, its moment of inertia and the modulus of elasticity be denoted by $F$, $I$, and $E$, respectively, and the half length by $l$. Similarly, for each tie-rod we have $F_1$, $E_1$, and $l_1$ ($= DG$). Conceive a circle to be struck with center at $D$ and radius $= DG$. Denote the difference between the lengths $DG$ and $DB$ by $\lambda$; that is, $\lambda$ is the amount by which each tie-rod is too short to reach the extremity of the bar without inducing stress. In the production of the camber, the post, which is short and for local reasons is often made very thick, is considered as remaining unchanged in length.

When the ends of the tie-rod and bar on the right (and simultaneously on the left) are forcibly brought together (by screwing up a nut, for instance), they will be found at

some point $B'$. The end $B$ of the bar has been displaced sideways a distance $d$; and also displaced longitudinally a distance $c$, due to the thrust $T_0 \ cos. \ \beta$, $T_0$ being the tensile force induced in the tie-rod; while the tie-rod itself becomes elongated by an amount $c_0$ dependent on $T_0$. Between the quantities concerned we now have the following relations, from the principles of "Mechanics of Materials:"

$$d = \left(\frac{l^3}{3 \, E \, I}\right) T_0 \ sin. \ \beta = R \ T_0 \ sin. \ \beta \tag{4}$$

$$c = \left(\frac{l}{F \, E}\right) T_0 \ cos. \ \beta \ = N \ T_0 \ cos. \ \beta \tag{5}$$

$$c_0 = \left(\frac{l_1}{F_1 \, E_1}\right) T_0 \qquad = N_1 \ T_0 \tag{6}$$

(for brevity's sake $R$, $N$ and $N_1$ are used instead of the factors which they are seen to replace); and also, since the sum of the projections of $d$, $c$ and $c_0$ upon the line joining $B$ and $D$ must equal $\lambda$,

$$c_0 + c. \ cos. \ \beta + d. \ sin. \ \beta = \lambda \tag{7}$$

So far as its use in the analysis of this paper is concerned, the angle between the tie-rod and the tangent-line at middle point $O$ of the bar, is not supposed at any time to vary appreciably from a fixed value, which will be called $\beta$. Given all the quantities in these four equations except $d, c, c_0$ and $T_0$, these last-named can be easily determined; or, if $d$ is known by actual measurement, we do not need to know $\lambda$, but can determine $T_0$ directly from equation (4).

We are now ready to consider the cambered brake-beam when subjected to external forces in service. These external forces are the pressure on its middle point, 2 $W$, and the two reactions, $W$ and $W$, one from each brake-shoe; see *Fig. 4*, in which the vertical dimensions and the degree of distortion are much exaggerated to secure clearness in demonstration.

The continuous full lines $A \ O \ B \ D \ O$ in *Fig. 4*, represent the brake-beam in its cambered condition, with its extremities or joints $A$ and $B$ just touching the brake-shoes (and the latter the wheels), but as yet not under external pressures. As

the pressure 2 *W* is gradually applied (*i. e.*, increased gradually from a value of zero to a value of 2 *W*) the joints *A* and *B* experience corresponding pressures increasing to a final value of *W* at each joint. The dotted lines *A′ O′ B′ D′* show the members of the brake-beam in their final form and position under the system of three external forces, 2 *W*, *W* and *W*. (It may be that the pressure 2 *W* is applied at a point along the length of the post and not at its upper end, but this will not affect the analysis, since the 2 *W* would still be a force external to the frame-work or truss.) In reaching this final (dotted) position the joint *O* has moved through the distance *O O′*, or "deflection of the

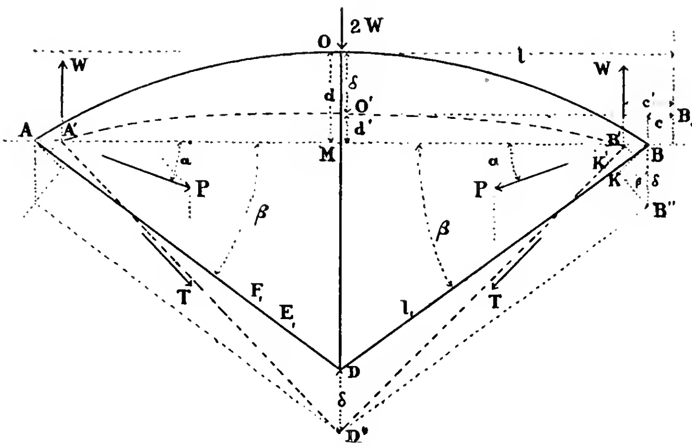


FIG. 4.

brake-beam," which we may call $\delta$. The lower end of the post has moved through an equal parallel distance $\delta$ (since the post does not shorten), while the joint *B* has moved along a line perpendicular to the post to a new position *B′* and (similarly, *A* to *A′* on the left).

As auxiliary lines, draw *B B″* equal and parallel to $\delta$ and join *D′ B″*; draw at *O′* a tangent line to the elastic curve of the bar, and verticals through *B* and *B′*. Let $O'\ B_0$ represent the unstrained length of the half-bar *O B*. Describe the short arc *B″ K′* with *D′* as center. *K″ B* may be considered a straight line and perpendicular both to *D′ B′* and to *D′ B″*. Also draw *B K* perpendicular to *B″ K′*.

Before application of the pressure 2 $W$, the deflection of the bar $A\ B$ was $= d, = \overline{O\ M}$, and the oblique force at its extremity $B$ was $T_0$, at an angle $\beta$ with $M\ B$. After application of 2 $W$, the oblique force acting on the extremity $B'$ of the bar is the resultant $P$ of the new tension $T$ now acting in the tie-rod, and the reaction $W$; and the deflection of the bar is $d' = \overline{O'\ M}$. $P$ makes some angle $\alpha$ (smaller than $\beta$) with $M\ B$, but need not be dealt with directly, being fully represented by its two components $T$ and $W$, in their respective positions; see *Fig. 4*. It is now required to determine both $T$ and $\delta$.

When the bar $A\ B$ was under initial stress only, the shortening of the half bar was $c$, and the thrust producing it was $T_0\ cos.\ \beta$, while the force producing deflection was $T_0\ sin.\ \beta$; whereas, after the application of 2 $W$, the shortening of the half-bar is $c'$, the corresponding thrust is $T\ cos.\ \beta$, and the force producing deflection is $T\ sin.\ \beta - W$.

Again, the difference between the lengths $D'\ B''$ (*i. e.*, $D\ B$) and $D'\ B'$, in other words the distance $B'\ K'$, is the excess of the elongation produced in the tie-rod by tension $T$ over and above that due to $T_0$.

We are thus enabled to write [referring to equations (4), (5) and (6) for the significance of $N$, $N_1$ and $R$]

$$\left.\begin{array}{l} c = N\ T_0\ cos.\ \beta\ ;\ c' = N\ T\ cos.\ \beta\ ;\ d = R\ T_0\ sin.\ \beta\ ; \\ d' = R\,(T\ sin.\ \beta - W)\ ;\ \text{and}\ B'\ K' = N_1\,(T - T_0). \end{array}\right\} \qquad (8)$$

We also note that the distance $B\ B' = c' - c$, i. e.,

$$\overline{B\ B'} = N\,(T - T_0)\ cos.\ \beta \qquad (9)$$

Projecting $B\ B'$ and $B'\ K'$ upon $B\ K$, we find that $B\ K$, which is $\overline{B\ B''}\ sin.\ \beta$, is made up of $B'\ K'$ and $B\ B'\ cos.\ \beta$, that is [see equations (8) and (9)]

$$\delta\ sin.\ \beta = (T - T_0)\,[N_1 + N\ cos.^2\ \beta] \qquad (10)$$

In *Fig. 4* it is evident that $\overline{O\ O'}$, or $\delta$, the deflection of middle of brake-beam, is equal to the difference between $O\ M$ and $O'\ M$; that is, between the value $d$, of the deflection of the bar $A\ B$ under initial cambering strain only, and that $d'$

of its deflection under final strain, which leads us, after noting the values in equations (8), to the relation

$$\delta = d - d' \text{ or}$$

$$\delta = R\,[W - (T - T_{\circ})\,sin.\,\beta] \tag{11}$$

If, now, we solve equation (10) for $\delta$ and equate the result to the right-hand member of (11), we obtain for the value of $T$ the tension in the tie-rod [after restoring the terms represented by $N$, $N_1$, and $R$, as evident in equations (4),(5) and (6)]

$$T = T_{\circ} + \frac{\left(\frac{l^3}{3\,E\,I}\right) W\,sin.\,\beta}{\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\,\beta}{F\,E} + \frac{l^3\,sin^2\,\beta}{3E\,I}} \tag{12}$$

This value for $T$ being substituted in equation (10) we determine the deflection of the middle point of the brake-beam under the pressure 2 $W$ to be

$$\delta = \frac{\frac{l^3}{3\,E\,I}\left[\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\,\beta}{F\,E}\right] W}{\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\,\beta}{F\,E} + \frac{l^3\,sin.^2\,\beta}{3\,E\,I}} \tag{13}$$

In most ordinary cases of metallic brake-beams the last term in the denominator of (13) is so large compared with the first two that the omission of the latter occasions but slight error. Calling these two terms zero, then, we have for the case mentioned

$$\delta = \left[\frac{l_1}{F_1\,E_1} + \frac{l\,cos.^2\,\beta}{F\,E}\right] \frac{W}{sin.^2\,\beta} \tag{13a}$$

If there were originally no camber in the bar $AB$, we should have $T_{\circ} = O$, and the tension $T$ for a given 2 $W$ would be correspondingly less, but the value of $\delta$ would not be affected; in other words, the brake-beam would be no stiffer with a camber than without, except as there might be some looseness at the joints due to faulty workmanship, if there were no camber. (A conclusion different from this might perhaps be reached if the stricter considerations of "Note A" in the first part of this paper were carefully fol-

lowed out.) However, initial camber is doubtless of utility in reducing the bending action on the bar $A\ B$, making the character of the final stress upon it almost purely a thrust, and thus rendering possible some economy in material; in other words, if a brake-beam of given dimensions is to be subjected to a given pressure $2\ W$ at the middle when in service, a certain initial camber can be assigned, such that the bar becomes practically straight when the pressure is applied, *i. e.*, becomes a column, or simple compression-member. This means simply that $\delta$ is to be equal to $d$ in *Fig. 4*, or that $d' = O$.

Making, therefore, $\delta = d, = R\ T_0\ sin.\ \beta$ from equation (8), we have

$$T_0 = \frac{\left[\frac{l_1}{F_1\ E_1} + \frac{l\ cos.^2\ \beta}{F\ E}\right]\frac{W}{sin.\ \beta}}{\frac{l_1}{F_1\ E_1} + \frac{l\ cos.^2\ \beta}{F\ E} + \frac{l^3\ sin.^2\ \beta}{3\ E\ I}} \qquad (15)$$

as a special condition for this case. Having solved (15) for $T_0$ in any numerical instance, we can then compute the corresponding value for $d$ from equation (8), and camber the brake-beam accordingly. The final thrust produced in the bar $A\ B$ will then be $T\ cos.\ \beta$, which $= W\ cotan.\ \beta$ [since $d'$ is to be zero; see equation (8)].

[NOTE B.—The expression for $T$ in equation (12) is identical with that derived by G. P. Ritter, C.E., who has used Castigliano's method of Least Work, in a thesis on the metallic brake-beam, written during his Senior year ('96–'97) in the College of Civil Engineering at Cornell University. Mr. Ritter applied this method as adapted by Castigliano to the case of a framework under initial stress.

This identity was to be expected, since in both treatments the consideration of shearing stresses is omitted and the bending moment in the bar $A\ B$ is assumed to be independent of the thrust component at the extremity.

The present writer has also applied a modification of Castigliano's other theorems, involving the "derivatives of internal work," and obtained a value for $\delta$ the same as that given in equation (13). Castigliano gives no direct method

for finding displacements of joints in a framework in which there are strains before loading; but if we write out the expression for internal work as due to the *excess* of each final stress over its initial value, the function so formed can be employed for purposes of differentiation, in obtaining displacements, which will be those occurring during the application of the external forces, *after the initial strains are set up.*]

Borrowing a numerical example from Mr. Ritter's thesis (see note B), let us apply equation (13) for deflection, to a steel brake-beam in which the bar or compression-member is a hollow cylinder, whose outer diameter is 2 inches and inner 1·62 inches, and length = 60·5 inches, with round tie-rods of 0·875 square inch sectional area, the angle $\beta$ being 18° 22′, and the load 15,000 pounds.

That is, using the units inch and pound, we have $l = 30·25$, $l_1 = 31·88$, $F = 1·08$, $F_1 = 0·875$, $I = 0·447$, $W = 7500$, and may take $E = E_1 = 28{,}000{,}000$; on substitution of which in equation (13) we obtain

$$\delta = 0·16 \text{ inch};$$

a result which, to quote Mr. Ritter, "is almost exactly what tests show for such a beam."

## The Jacques Carbon Battery.

By John W. Langley.

The experimental portion of the investigation of this subject was performed by two students, Messrs. H. S. Rosewater and W. H. Oldham, of the Case School of Applied Science, Cleveland, O., who made it the subject of a thesis, which is here partly reproduced. Some of the tables of readings have been omitted, but their results are represented graphically by curves.

Among those who have been attempting the direct production of electricity from carbon is Dr. W. W. Jacques, of Boston, who started the scientific world and general public

recently by his broad assertion that he had invented a process of making electricity directly from coal, and that his process was practicable and would revolutionize existing methods. He claimed for it an efficiency of 32 per cent. instead of the present value of only 6 per cent. or 8 per cent.

His apparatus, as embodied in a patent, consists of a closed furnace, which heats an iron pot about 6 inches in diameter and 2 feet deep, which is filled with caustic potash or soda, the alkali being kept in a melted state by the application of heat. The following sketch (*Fig. 1*) will serve to show the general character of his battery. In this melted

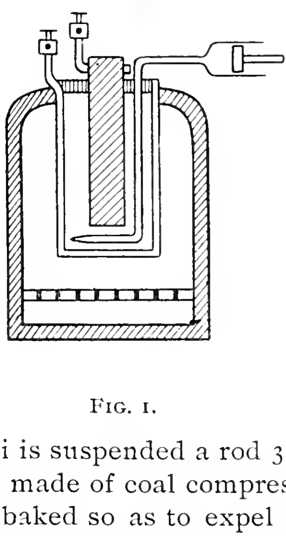

FIG. 1.

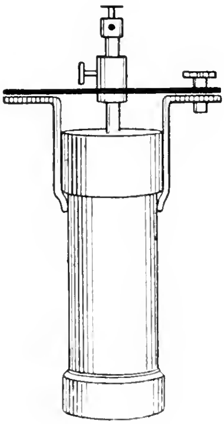

FIG. 2.

alkali is suspended a rod 3 inches in diameter and 20 inches long, made of coal compressed into sticks of the above size and baked so as to expel the included gases. This forms one plate or electrode of the battery, and is the consumable element.

In order to accelerate the action of the battery a supply of air is to be forced through an iron pipe, which terminates in a rose nozzle. Thus the air keeps the melted hydrate in constant agitation and at the same time supplies oxygen, which Jacques claims is necessary for the chemical action. With a cell of this size a current of 150 amperes at an E.M.F. of one volt is obtained.

A test made on a battery of 100 cells, each 12 inches deep and 1½ inches in diameter, showed that thirty 16-candle-power lamps were maintained for eighteen and three-quarter hours at full incandescence, the average E.M.F. being 90 volts, current 16 amperes, consuming eight pounds of carbon in the pots. The report claimed that "the actual electrical energy obtained from the carbon consumed in the pots was 82 per cent. of the theoretical." This efficiency, however, means nothing and is quite misleading, as it does not include the carbon consumed outside the pot to heat it.

Much discussion has arisen as to the cause of the current. Jacques says "that the electric current is due to the chemical combination of the oxygen of the air with the coke (carbon) there can be no doubt. Qualitative tests showed that oxygen was taken from the air, that carbon was consumed, and that the E.M.F. obtained agreed almost exactly with that which is theoretically obtainable from the combination of oxygen with carbon to form carbonic acid (1·04 volts)."

His opinions, however, have been criticised by men who have experimented a great deal on this subject. Mr. C. J. Reed claims that the action is, as proved by three experiments made by him, thermo-electric, or, rather, thermo-tropic, which term he applies to a thermo-electric junction between two metals, or two pieces of the same metal at different temperatures, and a solution of a salt or a melted salt, which does not act chemically on the metal immersed in it.

This paper will endeavor to show that no new theory need be put forth to explain the action of this battery, but only an old one applied. With the view of finding the correct reason for this extraordinary current, tests were made in which the following apparatus was used:

*A* A furnace.

*B* An iron pot.

*C* A pyrometer.

*D* An air blast.

*E* A gas burner.

*F* Various instruments to be described later.

The furnace was built of brick and contained the pot packed around with fragments of fire brick. A large multi-

ple gas burner, whose gas supply could be very accurately regulated, served as the source of heat, and by it the temperature of the pot could be quite exactly brought to any desired point and maintained nearly constant.

*B, the Pot.* The pot was made 12 inches in length, of 4-inch steam pipe, with a cap over its lower end. To its upper end were riveted two right-angled irons, which served as handles for the pot and also as one of the terminals of the electric circuit, as shown in *Fig. 2.* As the pot was too short to project through the cover of the furnace, a sheet iron sleeve was made to fit over the pot and between the upright handles. Over these two handles a horizontal iron bar was fastened with set screws. Through the center of the bar a collar passed, which held, insulated from it, a brass tube, to the upper end of which a binding post was fastened, the lower being slotted so as to hold either of the various rods to be experimented upon.

*C, the Pyrometer.* The temperature of the melted alkali was measured by a pyrometer of the Siemens type, which, as is well known, depends on the variation of the resistance of a platinum wire with its temperature, the wire being included in an electric circuit. The instrument consisted of a piece of ¾-inch iron pipe about 24 inches long, with a plug in its lower end. In the bottom of the pipe, and insulated from it by sheet asbestos, was a coil of platinum wire wound around a clay pipe stem, one end of the coil passed up through the stem, the other on the outside of the pipe stem and separated from the iron pipe by the asbestos. Both ends were fastened to copper leads at the top of the pipe.

Thus keeping the amperes constant in the coil, the volts, which varied directly with the resistance, which, in turn, varied directly with the temperature, were made to read the temperature by being properly calibrated. This was done by having an accurate mercurial thermometer immersed with the pyrometer in an oil bath, readings being taken simultaneously. The thermometer used read to 550° F. The current was kept constant by means of a rheostat at .25 amperes during the entire calibration, and also during all the experiments which follow. Two calibrations were made up to

350° C., at which point the oil took fire. A curve was plotted from these readings with volts and temperature as axes, and a straight line drawn through the majority of the points. A check was made on this line by finding the voltage at which zinc melted, and knowing the temperature a new point was found which agreed very closely with the line.

Compressed air was admitted to the pot by a ¼-inch iron pipe, which descended to the bottom and terminated in numerous small orifices.

The circuit was arranged as in *Fig. 3*. The instruments used were two ammeters, one reading to thousandths and the other to thirtieths of an ampere; also a voltmeter reading to thirtieths of a volt. A battery and rheostat were added for the pyrometer circuit.

By means of a two-point switch the voltmeter could be

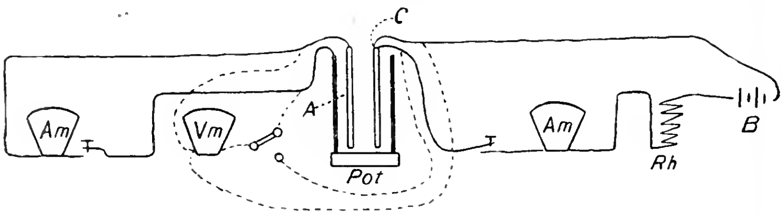


FIG. 3.

connected either with the pyrometer circuit or with the pot circuit, thus giving, in the first case, the temperature, and in the second the E.M.F. of the pot.

In *Fig. 3*, *A* is the carbon, iron or copper rod, *B* a battery, *C* the pyrometer, and *R h* a variable resistance. The readings were made in the same order in all of the experiments. (1) The pot voltage was read on open circuit and marked "Volts" in the diagrams. (2) The pot amperes read when the ammeter alone was in the circuit, designated by "Amps" in the diagram. (3) The pyrometer current was adjusted to .25 amperes, and the voltage read and reduced to its temperature equivalent, designated as "Temp" in the diagrams.

In order to avoid ambiguity in the following diagrams, the plus and minus signs are such that when the carbon, iron or copper rod is connected to one terminal of the out-

side circuit and the pot to the other terminal, the flow of current from the rod is the same as though these signs were applied to an ordinary liquid battery having its zinc pole marked "minus." The pot was grounded and, therefore, at O potential, always.

Seven experiments were made in the following order:

1 A copper rod without the air blast.

2 A copper rod with the air blast.

3 An iron rod without the air blast.

4 An iron rod with the air blast.

5 A carbon rod with the air blast.

6 A carbon rod without the air blast.

7 A carbon rod without the air blast, but with sodium nitrate added to the melted caustic soda in the pot.

All the materials used were of ordinary commercial quality, because these only could be economically used in a practical battery; therefore no attempt was made to employ chemically pure materials, as would have been the case if these experiments had been made in the interests of pure science instead of electrical engineering.

In experiment No. 1 a ½-inch copper rod was used, which was brightened before using, but which became coated with a dark scale, copper oxide, which scale was not disturbed for experiment No. 2.

Referring to *Plate I*, the curves of volts and temperature approach and recede from each other, *i. e.*, when the temperature goes up the volts drop, and when the temperature falls the volts rise; the same being true of the amperes, as shown by curve *V*, of *Plate VIII*.

In experiment No. 2 the same copper rod was used, and just enough air to keep the alkali from splashing. *Plate II*, together with curve *VI* of *Plate VIII*, show the results. The same general outline is observed, the volts falling as the temperature rises, and the reverse. The ampere curve, *Plate VIII*, curve *VI*, acts similarly to that of *Plate II*, except at the end of two hours and twenty-five minutes it rises to the maximum positive reading attained by any of the curves; in this case both curves become negative twice.

In experiment No. 3 a ½-inch iron rod was used, thus

making with the iron pot a hypothetical battery in which both electrodes or plates were of the same metal (which would exclude ordinary galvanic action), still, an E.M.F. was

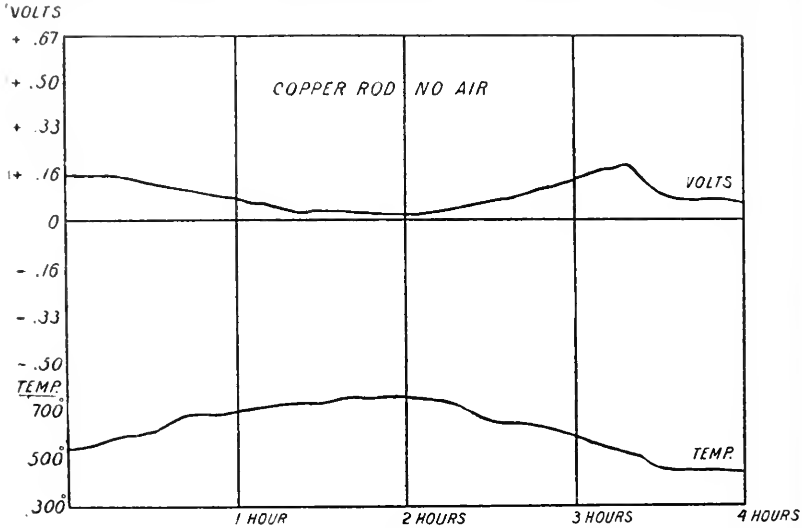


PLATE I.

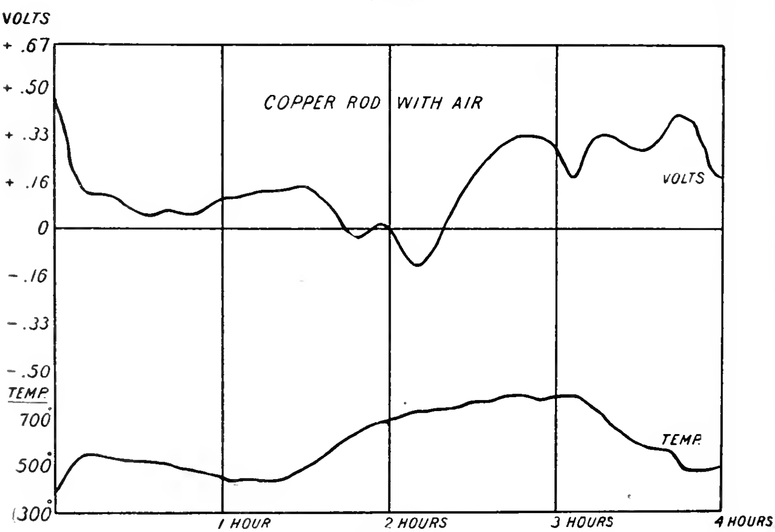


PLATE II.

created and a current circulated, as shown in *Plate III*, and in *Plate VIII* curve *VII*. The latter shows the general characteristics of thermo-electric action, the curve going

within ten minutes from a + value to — 4·5 amperes, the maximum negative value attained by the amperes.

Experiments 4, 5 and 6 show the same general relation

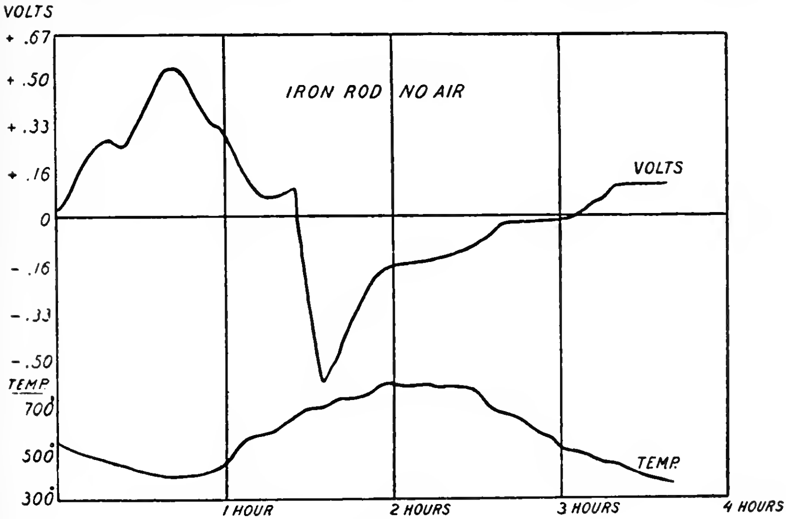


PLATE III.

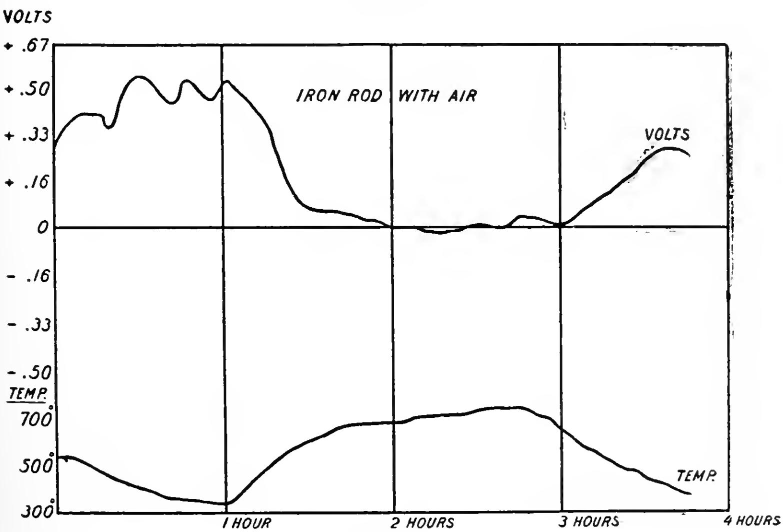


PLATE IV.

between rise of temperature and fall of volts, and it will be noticed that the E.M.F. produced by carbon against iron is not materially greater than that of iron against iron, as

shown by *Plates III* and *VI*. This is directly opposed to Mr. Jacques' theory, but to give his hypothesis every chance and to favor chemical action as much as possible, experiment

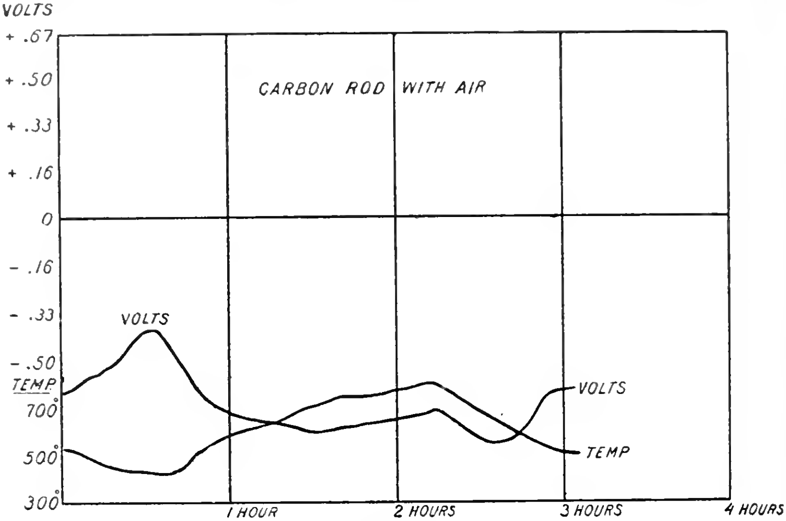


PLATE V.

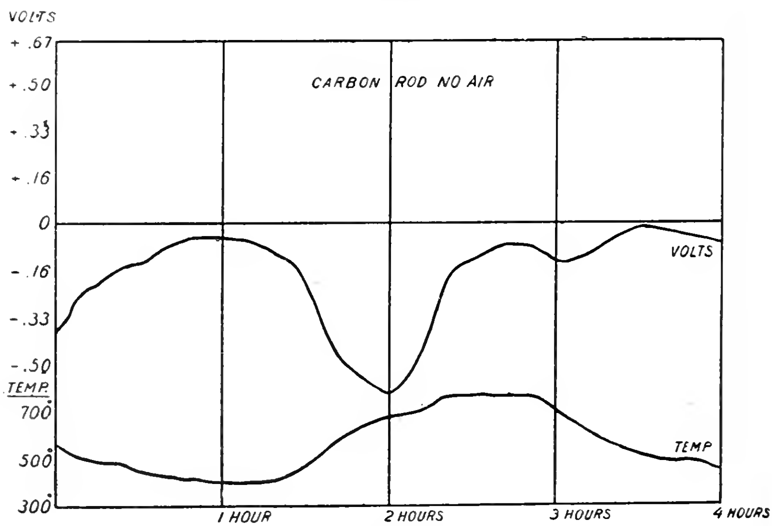


PLATE VI.

No. 7 was instituted, in which some sodium nitrate was added to the melted alkali in the pot. It would seem that if the voltage produced was caused by the oxidation of car-

bon, as Jacques asserts, the nitrate acting at a red heat ought to develop it, but *Plate VII* shows a diminished, not an increased E.M.F.

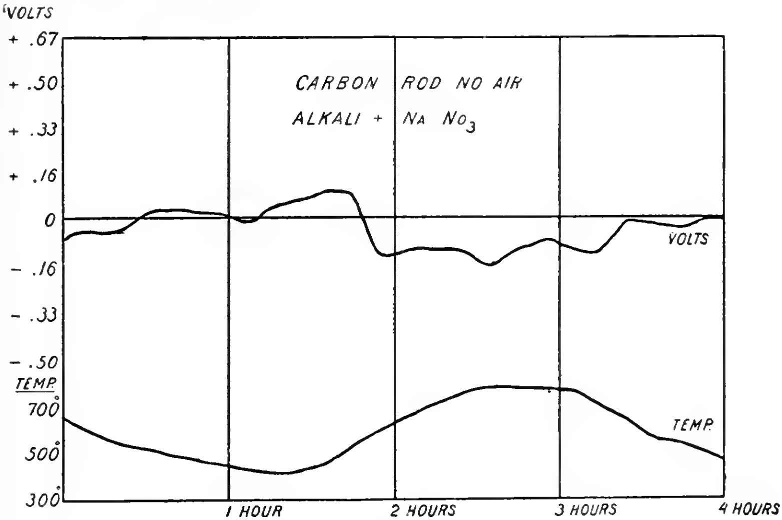


PLATE VII.

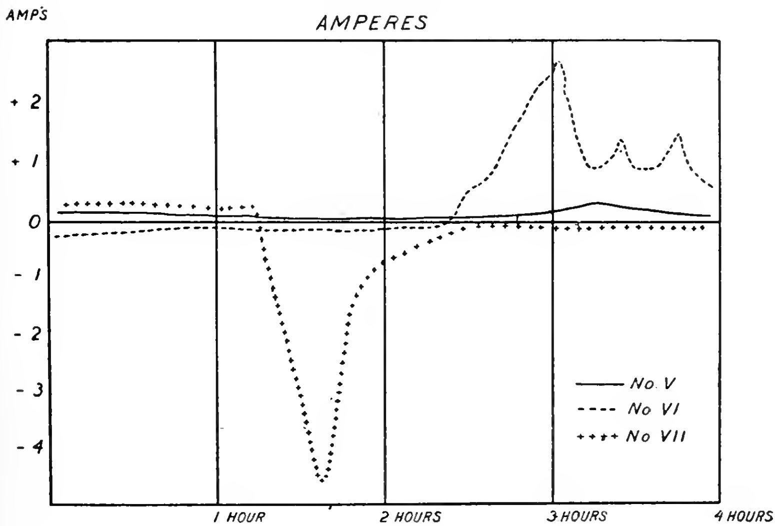


PLATE VIII.

That these experiments show the cause of the current to be thermo-electric there can be no doubt. In the first place the general appearance of the curves plotted is that of

characteristic thermo-electric curves by their sudden changes in magnitude and direction. Then the maximum voltage occurs when the difference of temperature is greatest; for such is the case on starting and stopping the gas (on starting, the pot becomes hot while the alkali remains relatively cool, and on stopping, the pot becomes cool while the alkali remains hot), which causes a great difference of temperature between the rod and the pot; this also shows a thermo-electric characteristic.

Also the addition of air would, if the action was chemical or galvanic, add oxygen and cause the curves of volts to become more negative, but this result is disproved in all the curves where air was used, and especially in *Plate VII*, where sodium nitrate was added, which held so much easily available oxygen, the curve being, in fact, positive instead of more negative.

Then again, the addition of air, air much colder than the melted alkali within the pot, would, if the action was thermo-electric, cause the voltage to be greater at starting and stopping the experiments than if it were not used, and also than during the interval between starting and stopping, a result shown just as expected in all the curves where air was used when compared with those in which the air was not used. Mr. Reed also stated that when ordinary illuminating gas was injected into the pot, no different results were obtained. Why should they be? Cold gas will cause the same effect as cold air if the action is thermo-electric, and not galvanic. That it is thermo-electric these experiments seem to conclusively prove.

The E.M.F. shown in this paper is much smaller than that stated by Jacques, and reported by other observers. The cause of this is probably due to the small diameter of the pot used, and to the very gradual and even heat employed, which greatly tended to lessen the differences of temperature between the two electrodes, that is, between the rods and the iron shell of the pot, for it is this difference only which causes the E.M.F. observed, according to the views put forth in this paper.

CASE SCHOOL OF APPLIED SCIENCE,
CLEVELAND, O., July 1, 1898.

# BOOK NOTICES.

*The Phase Rule; a Treatise on Qualitative Chemical Equilibrium.* By Wilder D. Bancroft. *The Journal of Physical Chemistry*, Ithaca, N. Y. Large 8vo. Pp. 252. Price, $3.

The object of this book is to classify the different types of heterogeneous equilibrium according to the phase rule of Willard Gibbs. Since only qualitative equlibrium is considered, the use of mathematics has been unnecessary; the graphical method alone has been employed. The result is a book which can be read profitably by anyone who has grasped the possibility of representing a function of one variable in terms of rectangular co-ordinates.

Some clue as to the sense of the displacement of equilibrium by change of pressure and temperature was necessary; this is supplied by the "theorem of Le Chatelier," that is, that the change which occurs when heat is added to a system in equilibrium is associated with the absorption of heat; when the pressure is increased the equilibrium is displaced in that direction which is identified with reduction in volume, or, in general, any action from outside produces a reverse change inside the system. Neither this generalization nor the phase rule is proved: the book is concerned entirely with the working out of their applications to the phenomena. This omission is not to be regarded as a defect in the work, for it lies outside its plan. Further, Gibbs' work has been made accessible in a German translation by Ostwald,* and the thermodynamic treatment of the generalization of Le Chatelier is to be found in various text-books, notably in the recent remarkable work of Duhem.†

The author has kept rigidly inside the lines of his plan, and has worked out the details in a most satisfactory way. His knowledge of the literature of this extensive and rapidly developing subject is extraordinarily comprehensive and minute, and the book contains many facts that will be new to most of us. New to the reviewer, for instance, were the interesting qualitative proofs of the vapor pressure of metals (p. 16) and the remarkable case of the system composed of hexa-chlor $\alpha$ keto $\gamma$-R-pentane and penta-chlor-monobrom-$\alpha$-keto-$\gamma$-R-pentane, in which, at the freezing-point, a solid solution invariably separates, which has the same composition as the liquid phase remaining, so that at all concentrations the liquid solidifies without change of temperature.

The direct conciseness of the English would be difficult to improve, yet there are some cases in which the straining for brevity has led to omissions which have destroyed the intelligibility of a sentence. The same cause has led in one or two instances to crowding data into one diagram which would have been more judiciously presented in two or three. The author's constant exposition of the blunders of other people detracts a little from the dignity and interest of the book. One is likely to get the idea that some of the remarkable men who have worked in this field, notably Ostwald, have distinguished themselves chiefly by making a series of absurd mistakes. One

* "Thermodynamische Studien, von Willard Gibbs." Leipzig, Engelmann.

† P. Duhem, "Traité de Mécanique Chimique," [1], 181.

must admit, however, that the criticism (p. 100) of Ostwald's famous proof that if two liquid phases are in equilibrium they must both emit the same vapor* is incisive. It will startle those of us who, like the reviewer, have for years accepted the proof as sound.

The reviewer notes with pleasure the adoption and consistent use of the nomenclature of Trevor for the different types of heterogeneous equilibrium. Of course, anyone who is interested in the development of chemical theory must have the greatest admiration for the brilliant work of Bakhuis Roozeboom, yet the fact remains that his nomenclature was merely a makeshift and the science will be advanced by its replacement by the terminology of Trevor, which leaves little to be desired in point of accuracy and conciseness.

In conclusion, it may be said that the defects of the book are trifling and its merits of a high order. It may be read with profit by chemists, no matter what particular sub-division of the science they cultivate. The appearance of such a book in English should do much toward ending the anomalous state of things in which some chemists refuse to concern themselves with topics like chemical equilibrium and the speed of reactions, on the curious ground that these subjects belong to the province of physics.

The book has been appreciatively reviewed by Roozeboom† and by Le Chatelier.

ROBERT HART BRADBURY.

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*Stones for Building and Decoration.* By George P. Merrill, Curator of Geology in the United States National Museum. Second Edition, revised and enlarged. New York: John Wiley & Sons. 1897. Price, $5.

The present edition differs from the first, issued in 1891, principally in the addition of some fifty pages upon the onyx marbles or travertines, for which reference is made to the author's paper in the annual report of the United States National Museum for 1893.

The added portion, like the rest of the book, is beautifully illustrated. Amongst the photographic reproductions is one showing the annual outcrops of onyx marbles in Lower or Baja California.

The author gives a table showing the composition and physical characteristics of onyx marbles from Egypt, Persia, Arizona, California, Mexico and other localities, and describes at some length the ancient and modern uses of these stones and the various foreign and American localities. J. C. T.

## NOTES AND COMMENTS.

### ARTIFICIAL DIAMONDS.

A new process for producing artificial diamonds has been experimented on successfully by Dr. Quirino Majorana (*Rendiconti della R. Accademia dei Lincei*). The present method consists fundamentally in heating a piece of

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**Lehrbuch der Allgemeinen Chemie*, [1] P. 645.

† *Journal of Physical Chemistry*, [1] p. 559 (1897).

carbon by the electric arc, and then submitting it to a violent pressure by means of a small plunger actuated by a piston, on which a pressure of 5,000 atmospheres was suddenly developed by explosion. When a sufficiently strong cylinder had been constructed to withstand this enormous pressure, the experiment produced a black mass consisting largely of graphite and amorphous carbon. On employing Berthelot's method to isolate the diamonds if they existed, small microscopic crystals were obtained, mostly black and opaque, but which exhibited all the properties of true diamonds, notably in their manner of burning at a high temperature. The conclusion drawn from these experiments is that pressure and heat are alone sufficient to transform amorphous carbon into the crystalline or diamond form, and that the presence of a metallic solvent, as in Moissan's experiments, is not essential to the transformation. W.

## PENETRATING POWER OF LIGHT BODIES.

A curious illustration of the power of light matter to perforate more substantial substances when driven at a high velocity is stated by the *Engineer* to have occurred in the Royal Arsenal a few days ago. In the course of experiments on firing gas in mines, conducted by Captain Cooper Key, R.A., under the Home Office, a special gun is employed to do duty for a bore-hole with a charge of high explosive, and pressed cylinders of raw dry clay, 3 inches long and 1⅞ inches in diameter, are used to represent tamping. These "shots" are made to act in various mixtures of air, coal-dust, gas, etc., and to stop the course of plug, etc., eventually, a cast-iron target plate, 1 inch thick, was placed 25 feet in front at an angle of 45°, in order to break up everything into dust and throw it upwards. After three or four shots with this arrangement, the clay plug, weighing 7½ ounces, perforated the inch iron plate, and the hole thus made has been steadily extended since. The familiar tallow candle passing through a door must hide its head before a 7½-ounce plug of clay perforating an iron plate an inch thick at an angle of 45°. Doubtless the velocity must be tremendous. It is pointed out that the velocity for a hard cylinder of this weight and size to cut through an inch of wrought iron at 45° would be over 1,800 foot-seconds. With cast iron and clay and the three or four repeated blows, everything is so greatly altered that there is little more to be said than that the effect is remarkable and unexpected. W.

## WELSBACH'S NEW ELECTRIC INCANDESCENT LAMPS.

There have been many rumors afloat of late respecting the latest inventions of Dr. Auer von Welsbach, which are directed towards the improvement of the electric glow lamp in respect both of duration of service and light efficiency. In both these directions it must be admitted there is room for substantial betterment, and Dr. Welsbach will deserve well of the public and will reap a substantial reward should he succeed in realizing the expectations he has raised.

The publication of certain patents recently granted to Dr. Welsbach suffices to give a general outline of the direction in which he is working.

The patents here alluded to describe two kinds of glow-bodies for use in incandescent electric lamps. The first is a fine filament of osmium of a peculiar form. Osmium is one of the metals of the platinum group, generally found in nature in the form of flat irregular grains, associated with iridium in the mineral called osmiridium. It may be obtained in the pure state by a chemical method of separation, in which advantage is taken of the fact that the tetroxide, which is readily formed by heating the metal in the air, is a volatile compound. It must be prepared, however, with great care, because of the extremely poisonous character of its fumes.

The second glow-body described is one formed of "thoria" and earth-metal oxide which is already largely employed in the preparation of the well-known Welsbach incandescent gas mantles.

Referring to the osmium filament, the basis of its selection as the substitute for the carbon filament is the claim made by the inventor that it does not volatilize at the highest attainable temperature when confined in a vacuum or surrounded by a reducing atmosphere.

A serious difficulty with the carbon filament in the ordinary electric glow-lamp, is the rapid darkening of the glass by the deposit on the inner surface of the glass bulb, of carbon volatilized by the heat of the current, or mechanically worn off by its passage. From this cause the light emission of the common electric glow-lamps is rapidly reduced, and it occasionally happens that they must be discarded long before the filament itself is broken. It is principally to avoid this defect of the carbon filament that Welsbach has had recourse to osmium. The present difficulties attending the production of his osmium filaments, however, are so great that it appears gravely doubtful if the method can be made commercially valuable.

The fact that it is impracticable to fuse osmium (and on this great infusibility its value for Welsbach's purpose depends) makes it impossible to obtain it in any other form than that of a powder which cannot be united into a solid mass by pressure and then drawn into wire. It becomes necessary then to obtain the osmium filament by indirect means, and for this purpose Welsbach deposits it on a fine platinum wire maintained in an atmosphere of hydro-carbon vapor mingled with water vapor (*sic*); and the platinum wire being heated to incandescence in this atmosphere by the electric current, small quantities of the vapors of osmium tetroxide are blown in from time to time. The result is that a thin layer of metallic osmium is deposited on the platinum wire. This operation, it would seem from the published account, is a slow and exceedingly delicate one, for the deposited film must be quite uniform to answer the purpose, since any irregularity in the deposit would affect the uniformity of its resistance and yield a light more brilliant in spots. Another method of obtaining the deposit is described, which consists in drawing the fine platinum wire through the solution of an osmium salt, and then glowing it in a vacuum. To obtain the film in the required condition, by this method, only an infinitely thick layer must be formed at a single operation, so that it must be repeated many times (100 times at least) to obtain the needful uniformity in the superposed layers. Neither of these methods, therefore, seem to present much promise of success on the commercial scale.

A more practical method suggested is to use vegetable or animal fibers as the foundation for the osmium coating. A liquid pulp is made by mixing the

finely comminuted osmium oxide and the fibers with sugar solution or other organic cementing material, and, after drying and cutting into the required shape for the lamp, it is glowed slightly in an atmosphere of reducing gas. By this and slightly modified methods, a carbon skeleton is formed carrying a certain quantity of unconsolidated osmium. These methods appear practical; but it will be observed that the resulting filament is not a pure osmium filament, but one consisting largely of carbon, and hence open to the same objections as the common carbon incandescent lamps, besides being vastly more costly.

The second proposal of Welsbach is the thoria filament.

This substance, as above remarked, is one of the rare earths largely used in the manufacture of the Welsbach gas mantles, and is known to possess light-emitting qualities of a high order.

To obtain this filament the inventor employs an extremely thin platinum wire (0·02 millimeters in diameter) approximately as thin as a single fiber of the silk cocoon, and draws this successively through elastic cheeks which are kept moistened with a solution of salt of thorium. After each drawing the wire is glowed, and the operation must be repeated, as in the one above described, many times, in order that the resulting coating shall have the necessary permanency.

The resulting thread, then, is a platinum core, surrounded by a dense incrustation of thoria. The heat-resisting qualities of the incrusting oxide are said to be so great that the platinum wire within may be melted without affecting it, while the amount of heat radiated from the brilliantly luminous thoria is comparatively small. With the current intensity employed for ordinary illumination, however, the platinum core is not melted, the explanation being that the greater part of the heat energy imparted to the platinum is transformed by the fire-proof encrusting material into light; the intense power of the coating to emit light withdraws and transforms much of the heat of the metallic conductor into light.

The above description gives merely an outline of the several methods set forth in Welsbach's recent patents. In view of the great expectations raised by the reports of his remarkable laboratory work, it must be confessed that the outcome is a disappointment. While the methods proposed are ingenious, they seem to be altogether too delicate to be capable of being commercially applied, and they are undoubtedly so costly as to place serious competition with the cheap electric glow lamp, with which we are familiar, out of the question. W.

## THE MINERAL PRODUCTION OF THE UNITED STATES IN 1897.

Mr. Richard P. Rothwell, C.E., the well-known mining engineer, and editor of the *Engineering and Mining Journal*, has just issued Volume VI of the valuable statistical publication, "The Mineral Industry," giving the complete statistics of the production of minerals and metals in the United States in 1897.

From this excellent compendium it appears that the total value of the mineral products of the United States in the last calendar year was $678,956,644.

The principal items making up this magnificent total were: gold, 2,864,576 ounces, valued at $59,210,795; silver, 56,457,292 ounces, of the value of $33,-755,815; copper, 510,190,719 pounds, valued at $56,325,055; lead, 197,718 tons, valued at $11,784,093; zinc, 100,387 tons, of the value of $8,271,889; iron, 9,652,680 tons, valued at $92,677,312; coal, all forms, 200 259,243 tons, worth, in round figures, $250,000,000; clay products, various kinds, valued at $60,000,-000; crude petroleum (in round figures), 8,000,000 barrels, of the value of $44,804,962; natural gas of the value of $10,000,000; building stone of the value of $30,000,000.

The significance of these figures will perhaps be best appreciated by comparison with those of European countries. On this point, the following statement, made at the close of the year 1896, holds equally good for the year 1897, viz.: "The total value of the output in 1896 (which had an estimated value slightly less than that of 1897) exceeded that of the mineral and metal production of all Continental Europe, and nearly doubled that of the United Kingdom, the value of whose mineral output in 1896 was, in round figures, about $340,000,000, while that of Germany was about $300,000,000, that of France about $110,000,000, and that of Belgium about $100,000,000."

Certain items in the statistical table accompanying this volume have a peculiar interest. Thus, the increase in the production (about 230,000 ounces, about $7,000,000) over that of 1896, although considerable, is not so large as would be anticipated from the large output of the Klondike region, for the reason that by far the larger portion of the yield of that great northwestern country is obtained from British-American territory. Also, the production of pig iron and coal in 1897 was the largest in any single year in the history of the United States. The production of silver exhibits a decrease as compared with the figures of the year previous of almost exactly 2,000,000 ounces, which is attributed to the heavy decline in the market price of silver, which compelled the closing of a considerable number of heretofore productive mines, and incidentally also exerted a deterrent influence upon the development of new mines.

The production of aluminum in 1897 exhibits a large comparative increase, being 4,000,000 pounds ($1,400,000), as compared with 1,300,000 pounds ($520,000) in 1896. This increase is ascribed in part to the reduction in the price of metal and in part also to the development of a considerable export trade.

The new product, calcium carbide (from which acetylene gas is made), appears in the tabulation with an output estimated at 860 tons, valued at $48,000. The growth of this industry, as these figures indicate, is thus far much less rapid than the sanguine expectations of those interested in the new illuminant led the public to expect.

The heavy chemical industries represented by such staple articles as soda and sulphuric acid exhibit a gratifying increase, the value of the first-named product rising from about $3,500,000 (in 1896) to $5,750,000 (in 1897), and the latter from $17,250,000 to $21,500,000.

The foregoing facts and figures make a most impressive picture of the annual increment to the wealth of the nation from the development of its mineral resources. W.

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## THE FRANKLIN INSTITUTE.

*Stated Meeting, May 18, 1898.*

## DIESEL'S RATIONAL HEAT MOTOR.

BY E. D. MEIER.

All power which man uses, and all forces which he tries to curb and turn to his own purposes, have their origin in heat. Whether we spread the sails of a clipper to a spanking breeze, or urge an ocean greyhound at nearly railroad speed across the Atlantic ferry; whether we propel cars in the streets of Buffalo with electric force generated by the Niagara Cataract, or carry heavy packs on the backs of horses over frozen Klondike trails, we are using in some form the energy poured forth in lavish profusion by the central orb of our system. His heat caused the air currents, which waft the ships to our shores; ages ago his rays called forth primeval forests, whose charred and compressed remains are fired under our steam boilers; vapors raised by his power from the waves of the ocean fall in life-giving

rains on our continent, alike raising the level of the Great Lakes, whose waters feed the mighty cataract; and, in co-operation with his direct heat, call forth bloom and fruit on the fertile fields whence man and brute nature alike derive their sustenance. Man, rising above the animal in his appreciation of the blessing of labor, first applied muscular force, and next what we are wont to designate as the natural forces, to assist him in his restless activity of production. Oars, levers, treadmills and all manner of harness for horse and steer preceded the use of wind or of falling water.

For centuries wind- and water-power were sufficient to drive all his machinery. The expansive force of steam, discovered by the ancient Egyptian, served but for a few simple actions, purposely enveloped in mystery to strengthen the superstition which priest-craft considered necessary for its schemes of government.

Even war, the delight, the pastime and the sole means of support of kings and nobles through many centuries, was slow in finding its most powerful agent in the explosive force of suddenly liberated heat. Finally, it was late in the seventeenth century that attempts were first made to utilize the expansive force of steam or of gunpowder in pumping water and for other useful purposes. And then, after the first experiments had demonstrated the tremendous force contained in these agents, these phenomena for a full century were of interest only to philosophers; and when Watt finally succeeded in harnessing the power of steam and making it work his will, inventors were already busy with engines designed to produce motive power by the explosion of gas or vapors.

Through all these centuries the forces employed were recognized by their effects, and no one suspected that the primal cause of all was the power of heat. Or, if we see in the early worship of the sun, as the great life-giver, some dim appreciation of this great physical fact, it had never yet risen to the height of faith or knowledge, nor had any one dared to attempt to measure and weigh heat in units of force.

The first heat motor which became a practical success-

the steam engine—was for many years developed simply by gradual improvement of its mechanical appliances without any appreciation of the fact that heat economy was the primal consideration. It was, perhaps, well that this was so. Had the early inventors and designers of steam engines understood the limitations to which the steam engine is subject, they would hardly have attempted to develop a machine which, after 100 years of experiment, and another century of practice by the master minds of each generation returns in work less than one-seventh of the potential energy residing in the fuel with which it is fed. And had they turned their attention to machines aiming at more direct transmutation of heat into work, the mechanical difficulties which would have confronted them might have retarded the industrial progress of the world by a full century; for, with all its defects as a vehicle of heat energy, steam has at least the one advantage that it can be used at very low pressures. The early engine gave results which, for the time, were of sufficient and even great value with pressures of less than 10 pounds to the square inch. Materials for higher pressures and temperatures were not available. These materials themselves had to be produced in larger variety and of better quality so that gradual increase in the pressure carried should give us as gradual an increase in fuel economy.

If the early inventors of internal-combustion motors were proceeding on more rational lines, so far as the final outcome was concerned, they were kept back, and in many instances their efforts were foiled altogether by physical difficulties which required greater knowledge of metallurgy and greater mechanical skill than the world then possessed. For a full century the steam engine dominated the whole industrial field, and, until twenty years ago, it stood without a rival.

To an American engineer, Benj. Thompson, also known as Count Rumford, the world owes the first attempt to find an equivalent of heat in work, and the discovery that heat is not matter, but a form of energy. This important fact was communicated by Thompson, then residing in Munich, Bavaria, to the British Association for the Advancement of

Science, just 100 years ago. Other experimenters followed, but it was not until much later that Joule, in England, and Mayer, in Germany, determined and fixed the mechanical equivalent of heat. Early in this century, Sadi Carnot, in France, developed the theory of a perfect heat engine, yet it was a long time before the clear reasoning of these men, though enthusiastically received and elaborated by Rankine, Zeuner, our own Thurston and others, found its way into the designing room of engine builders. For a long time the steam engine was studied only in its mechanical aspects, and the striking success of Corliss, while a great stride toward mechanical perfection, tended rather to retard than to accelerate the study of the steam engine as a heat engine. It is still within the memory of most practicing engineers of to-day, that Hirn, by his wonderful series of experiments at Mulhouse, and his beautiful analysis of the results, aroused mechanical engineers to the importance of considering the utilization and conservation of heat in the steam engine, as the fundamental question of design.

Naturally enough then, when steam was once recognized, not as the cause, but merely as the vehicle of the energy to be transformed into mechanical work, interest was revived in other heat motors. The experimental work of the beginning of the century was looked up, and the means and methods of the earlier inventors of engines, employing gas or oil vapors, were examined by many scientific and skillful engineers, who believed that there must be a more direct way of converting heat into work, than the one through furnaces, boilers, and a long line of steam piping to the cylinder where the conversion takes place.

Isherwood's conclusive experiments in regard to the waste resulting from the physical properties of steam, had their due influence. Higher temperatures were sought, resulting in higher pressures, reheating, and in increasing the number of cylinders. From the 4 to 8 pounds pressure of the earlier days, which could be contained in wooden boilers, such as some of you may remember to have seen in the Water Works in the city of Philadelphia, we have advanced to the 200 pounds and more, carried by the great

marine boilers of our ocean greyhounds and cruisers, and engineering schools possess experimental engines intended to determine the practicability of going up to 300 and even 500 pounds to the square inch. The vast industrial development brought about by the steam engine has given us metals, methods and data, which enable us to contemplate such pressures with equanimity, and have developed lubricants capable of withstanding temperatures which ten years ago were prohibitory.

A little more than a year ago, Professor Thurston published a scholarly discussion of the "Promise and Potency of High-Pressure Steam." His data were compiled from a number of careful tests on the triple and quadruple expansion engines of Sibley College, engines specially designed and admirably handled with a view to determining the possibilities and limits of progress in that direction. He concluded as follows:

"With equally excellent design, construction and management, we may expect the efficiency of the steam engine, with increasing pressures, to increase nearly as the logarithm of the boiler pressure.

"Gain in economy, by increasing pressures simply, must be expected to be slow and to steadily decrease in rate of gain as pressures rise, making the practicable, commercial limit a pressure comparatively low.

"The direction in which to seek for gain are the reduction of internal wastes and the production of a superheated steam engine."

According to this, if we can count in practice on 12 per cent. absolute efficiency with steam at 200 pounds, 14·2 per cent. would be the outside limit at 500 pounds, and 15·6 per cent. at 1,000 pounds steam pressures.

And in this reasoning the increasing difficulties of steam production and boiler economy at the higher pressures have not been considered. As he elsewhere finds cylinder condensation to account for from 18 to 34 per cent. of the total steam expended, the use of some more reliable vehicle for the heat than steam becomes imperative. Thurston's critical examination of the future prospects of the steam engine

then points the way to the production and direct application of the heat at the very point where its energy is to be translated into work.

Thus, after an exhaustive analysis of experiments made with special steam engines of a higher and more developed type than are as yet to be found in practice, he arrives at definite conclusions which confirm and fix in exact limits the prophecies of men like Zeuner, Rankine and a host of others who have given eloquent testimony to the fact that the steam engine is wrong in principle. Thirty years ago Redtenbacher wrote to Zeuner that "the principle of steam generation and utilization is wrong; it is to be hoped that at a time not far distant, the steam engine will disappear after we have acquired clear ideas on the nature and effects of heat."

All these utterances of men of genius naturally led to a renewal of interest in the internal combustion engine. Ericsson's brilliant failure in his attempt to substitute air for steam, and the final relegation of the hot-air engine to very small domestic pumping plants, seemed to put air out of the question as the vehicle for the heat.

The internal-combustion engine, experimentally developed by Barnett, in England; Drake, in America, and Lenoir, in France; improved by Brayton, Barsanti and others, and ably discussed and advocated by Dr. Siemens, became a practical motor in the hands of Otto in 1876. Otto's master patent, at first attacked as being but an adaptation of Beau de Rochas' theories, was sustained in the leading patent offices of the world, and became the foundation on which men like Priestman, Crossley, Atkinson, Capitaine, Clerk and others too numerous to mention, developed infinite varieties of type with a gradual and satisfactory increase in economy.

But they all worked in more or less beaten paths. The value of compression of the charge before explosion was recognized as increasing the initial pressure in the working cylinder. Means and methods for producing retarded combustion (the Nachbrennen of the Germans), or of slowing down the explosive action, were proposed and criti-

cised with equal acumen and quite an expenditure of thermal units on the part of the disputants. Some of the mechanical devices evolved, reflect the greatest credit on the skill and persistence of their inventors. But no one attempted a vital change in the cycle itself until Diesel appeared in the lists. Untrammeled by any previous experience in gas- or oil-engine construction, he was intent only on giving the clear and beautiful ideal of Carnot practical and tangible form in a working engine. He experimented with various vapors more permanent than steam, until the very mishaps and difficulties encountered brought him face to face with the fact that the atmosphere about us could furnish a cheap, endless supply of a permanent gas, available not only as the vehicle of the heat, but as the means of evolving it from the fuel employed.

Rudolf Diesel is a Bavarian, forty years old. He received his early education in Paris, where his parents then resided, until they were forced to emigrate, in 1870, by the decree of the moribund Empire. He is a man of strictly temperate habits, a good mathematician and thoroughly versed in the science of thermo-dynamics, which he has made his life study. As a student at Munich, he was a pupil of the celebrated Professor Linde, now well known as the inventor and builder of the excellent ice machine which bears his name. Since the publication of his lecture of June 16, 1897, he has been fairly overwhelmed with praise and congratulations by the leading professionals of Europe. Perhaps no better gauge of the strong common sense and real greatness of the man can be found than the fact that all this praise and adulation has not turned his head in the least. He remains the same simple, earnest, conscientious student that he was before his great invention dazzled the experts in his line of engineering.

I was particularly struck with the simplicity, and I might almost say humility, with which he spoke of his great achievements. He considers his present success only as an incentive and a stepping-stone to further work and progress. He is very accurate in all his statements, and

thoroughly honest. Nothing can induce him to confound even his most sanguine hopes with a promise of any future success. He patiently and good-humoredly answered all my questions, and was instantly ready to show me authorities for his statements from the carefully chosen books of his extensive library.

As an engineer, he is more theoretical than practical, but has now at his command some of the best practical talent of Germany. Professionally well equipped and clear in his ideas, he is so simple and amiable in his manner that it is a pleasure to work with him, and these characteristics of the man promise to make the working together of the various interests in the many countries in which he has issued licenses satisfactory and beneficial to all, and will make a rapid progress in the practical development of the invention possible.

Mr. Diesel has been at work on the theories on which this motor works ever since he was a student at the Munich Polytechnic School. For the past fifteen years he has devoted himself almost entirely to this work. He even built a small experimental motor in Paris many years ago, the working of which enabled him to modify his first theories considerably. He, however, took the precaution to have the parts of this motor constructed in different shops to prevent his ideas and processes from becoming known. In 1892 he made his applications for his first patent in different countries.

In 1893, then residing in Berlin, he published a book on a new motor, which was translated in 1894 into English by Mr. Bryan Donkin, M. Inst. C.E., under the title "Theory and Construction of a Rational Heat Motor." In this little book Mr. Diesel developed an entirely new idea. It was this: To begin the work of combustion by first compressing atmospheric air to a point where its heat would become sufficient for ignition, and then gradually forcing into this compressed air a small quantity of pulverized fuel. This whole work was to be done in the cylinder of the motor, so that no heat would be brought into it from without. Mr. Diesel not only developed the theory, but suggested the

leading principles of construction. At the time this book hardly went further than into the libraries and studies of men specially interested in the theory of thermodynamics. But Mr. Buz, of Augsburg, the general manager of the great machine works there, placed means and men at the disposal of Mr. Diesel, to enable him to work out his theory in practice, and a 12 horse-power motor was built there, on which many experiments were made. The improvements suggested were embodied in a second machine of the same size, and from this was evolved the 20 horse-power motor which established the working type now adopted. Mr. Fr. Krupp, of Essen, the German Steel King, also became interested in the matter. Mr. Diesel moved to Munich so as to be able to give his whole time to this work.

In the meantime, in 1895, a Mr. Schmidt, of Cassel, worked out and exhibited a steam engine working with highly superheated steam. For the time this motor attracted the attention of the engineering world; its defects were, however, so apparent that it did not come into general use, but it did serve to withdraw attention from Diesel and his work. On the 16th of June, 1897, Mr. Diesel delivered a lecture before the National Society of German Engineers at Cassel, in which he not only developed his theories, but exhibited in drawings the actual construction of his motor, and gave some data in regard to practical results obtained at Augsburg. Prof. M. Schroeter followed Diesel in further development of the theory of the motor, and gave in detail the results of tests made by him on the first experimental motor, and stated his conviction that the motor was now ready for commercial work. (These essays were published in the *Zeitschrift des Vereins Deutscher Ingenieure* of July 10th, 17th and 24th, 1897.)

At the conclusion of these papers a wave of enthusiasm swept over the large audience of professional engineers, and the desire naturally arose to see the motor at work. Mr. Diesel extended invitations to all engineers and manufacturers to visit the works at Augsburg and examine and test the motor for themselves. This invitation has been so generally accepted that for the next nine months the motor

was practically on exhibit for every hour of the day, under the closest inspection by engineers, not only from Germany, but from every civilized country. It was therefore necessary to keep it running as a petroleum motor, and not until a month ago was it possible to dismantle the engine in order to make the slight but important changes necessary to adapt it to experimental work on gas.

Mr. Diesel's idea was to follow Carnot's cycle strictly, obtaining the lower isothermal and adiabatic curves by compression and the upper ones by combustion and expansion. For a long time he experimented with various vapors, which, under normal conditions, are far above their point of condensation.

Ammonia vapors, especially, seem to have the properties best suited to the theoretical process. But great difficulties in handling them were encountered in practice. In the endeavor to replace them he was naturally led to experiment with air. Up to this time he had necessarily applied his heat from without and was subjected to the losses and limitations due to the metal walls through which it had to pass. He was then subject to the same losses which had defeated Ericsson, and was compelled to make the step which made his motor an internal-combustion engine. Starting out, then, with the intention of improving the caloric process of the steam engine, he reached, in a round-about way, means similar to those employed in gas and oil engines. But this similarity is strictly limited to the *fact* of internal combustion, the *method* of combustion being radically different. Further, finding that to begin his compression isothermally, led him into pressures which must, in our present practice, be considered excessive, he abandoned that part of the Carnot cycle and made his compression adiabatic throughout, thus reducing the necessary pressures from over 100 atmospheres to between 30 and 40. When, as in the history of the steam engine, these higher pressures become practically feasible, a return to the original complete process may become advisable. Mr. Diesel's fundamental invention is then really a process for converting heat into work; this, of course, has been supplemented by other in-

ventions naturally growing out of the persistent and logical development of a practical machine to operate on this process. I am happy to have available the description and opinion of no less an authority than Lord Kelvin, written by him after a careful investigation of Diesel's claims, and I will quote it in full.

"The invention may be defined as follows: (*a*) — (*h*).

"(*a*) Use a quantity of air very large in comparison with the quantity of fuel and which may be much larger than is required for complete combustion of the fuel. This air, at the beginning of (*b*) is at atmospheric temperature *T*; and is at a pressure somewhat above atmospheric pressure in virtue of the operation (*h*) described below, unless this operation is omitted.

"(*b*) Compress this air adiabatically to a temperature far above that required to ignite the fuel under pressure.

"(*c*) Immediately after the dense air thus heated has commenced to expand, inject into it the fuel, whether gaseous or liquid, or finely powdered solid, thus causing the fuel to burn as it enters and to prevent, by the heat so generated, the expanding air from going down in temperature.

"(*d*) Regulate and distribute through a prescribed portion of the working stroke of the working piston, the admission (*c*) of the fuel.

"(*e*) Use a governor to alter the duration and amount of the combustion (*c*) according to varying requirements of varying circumstances.

"(*f*) After the introduction of the fuel ceases, continue the expansion until the air is cooled sufficiently, nearly down to the atmospheric temperature (without any abstraction of heat by a water jacket). It becomes cooled to exactly the atmospheric temperature when it sinks to the atmospheric pressure, provided the concluding operation (*h*) of the cycle is properly adjusted, according to the extent of the operations (*b*) (*c*) (*d*) (*f*).

"(*g*) Reject the whole or part of this air from the machine, and take in fresh atmospheric air instead, to make up the whole quantity with which we commenced in (*a*).

"(*h*) Keep, now, this air at atmospheric temperature by

injected water, and compress it to such a pressure as shall cause the fulfillment of the condition stated at the end of paragraph (*f*). This operation may be advantageously omitted, with some sacrifice of theoretical thermodynamic economy, but probably with practical advantage, in smaller types of engine.

"If regulation (*d*) of operation (*c*) were so conducted as to keep the temperature at an absolutely constant degree (*S*) during the portion of the working stroke to which it refers the series of five operations (*b*) (*c*) (*f*) (*g*) (*h*), would constitute an absolutely perfect Carnot cycle for the production of mechanical effect from a quantity of heat given at the temperature *S*, with *T* as the lowest temperature available for carrying off waste heat. The conditions, of course, cannot be *perfectly* realized in any real machine; but Diesel has shown how to make a good, practical approximation to their fulfillment, whether the fuel be gas, powdered solid or oil. He has already, with oil as fuel, realized this approximation with exceedingly good practical results, and has actually obtained 58 per cent. more work than any that has been given, from the same weight of oil, by any of the best oil motors previously made.

"The best economy of oil motors recorded in *The Gas and Oil Engine*, by Clerk (Longmans & Co., 1896), is 371 grams of oil per B.H.P. hour, and the Augsburg tests of the Diesel engine give 234 grams of oil per B.H.P. hour.

"Besides this great advance in economy of fuel, Diesel's invention has given many collateral advantages of much practical importance. By supplying the fuel gradually to hot expanding air during a determined part of the working stroke of the main piston, and, by using a much larger quantity of air than that required for complete combustion, he keeps the highest temperature reached by his engine several hundred degrees centigrade lower than the temperature essentially reached in the working cylinders of previous gas and oil engines. And the expansion after the end of the combustion gives a much lower temperature of exhaust without cooling by water jacket, than both expansion and water jacket together give in other gas and oil engines.

"Diesel's process of heating the air, simply by compression, to a temperature far above the igniting point of the fuel, before the fuel is introduced to it, supersedes all use of flame or hot chamber for ignition, even when the engine, cold in every part, is started for its first stroke by energy stored in a compressed air vessel from its previous working. This capability for instant starting from cold, and for stopping and starting again with perfect readiness at any time, is, I believe, a very valuable item of superiority, for many practical purposes, over any gas or oil or other interior-combustion engine, previously made. Diesel's invention of introducing the fuel into air previously heated to far above the igniting point, merely by compression, and so causing the fuel to ignite, is, in my opinion, thoroughly original, and it has not been anticipated by any previous inventor. In nearly all previous gas and oil engines, the air and fuel are compressed after being mixed together, with the great disadvantage that the degree of compression cannot go beyond comparatively narrow limits without causing explosion before the compression has ceased. In Barnett's third engine, the air and gas are compressed in separate pumps which, after the compression, discharge their contents into the motor cylinder. There they are ignited by means of a flame controlled by an igniting valve invented by Barnett (being almost identical in principle with the igniting arrangements used by many subsequent inventors). But neither Barnett nor any subsequent inventor anticipated Diesel, in causing the fuel to be ignited by the high temperature produced by previous compression of the air into which it is introduced.

"Diesel is also quite original, and is, I believe, not anticipated by any previous inventor in gradually introducing the fuel into expanding air, and so regulating and controlling the temperature produced by the combustion."

I have just received a paper from a noted Austrian engineer, Mr. Emil Krauss, written after a careful personal investigation of the Diesel motor at Augsburg. Mr. Krauss is known beyond the limits of his own country as an expert on boiler construction and boiler management, and

his official position is such as to qualify and bias him rather as a champion of the steam engine than otherwise. Thus, when I quote his conclusions, I am giving you the conviction of a man whose interest is, if anything, inimical to Mr. Diesel, but whose professional integrity compels him to acknowledge excellence where he finds it.

"I saw such a motor at work in the Augsburg Machine Works last fall, and must state that it impressed me as a completely designed and finished machine.

"(1) The working process, such that heat is supplied only at high temperatures, fills the requirements of a rational heat motor better than any previous heat engine.

"(2) The temperature at which the addition of heat begins is entirely independent of the process of combustion, and is so high that the efficiency, even when a minimum of heat is supplied, cannot fall below that fixed by this initial temperature.

"(3) The influence of the temperature of combustion on the thermal efficiency is so small, that within certain limits this efficiency actually increases with the excess of air in which combustion is effected.

"(4) The regulation of the motor can be consequently accomplished without affecting its economy.

"The first petroleum engine embodying these principles has placed the Diesel motor at the head of all petroleum motors up to date. The same success is probable for the Diesel gas engine; work on this is progressing, and everything indicates that a new success for Diesel will shortly be recorded."

It was Diesel's first intention to build a motor with three cylinders embodying compound compression and compound expansion, and one of this type has been built at Augsburg, and is to be thoroughly tested on producer gas. But the development of the single-cylinder type has been so satisfactory, and the demand for them has become so great, that at present the German shops are busy to their fullest extent building this simpler form. As this form has reached an absolute efficiency of 30 per cent., and is in every way a simple and practical machine, there is at present no reason

for developing the compound motor. The cut here given (*Fig. 1*) represents the first of these 20 horse-power motors, built by the Nürnberg Machine Works. It is at present on exhibit at the Electrical Exposition in New York City. In appearance it resembles a vertical marine engine,

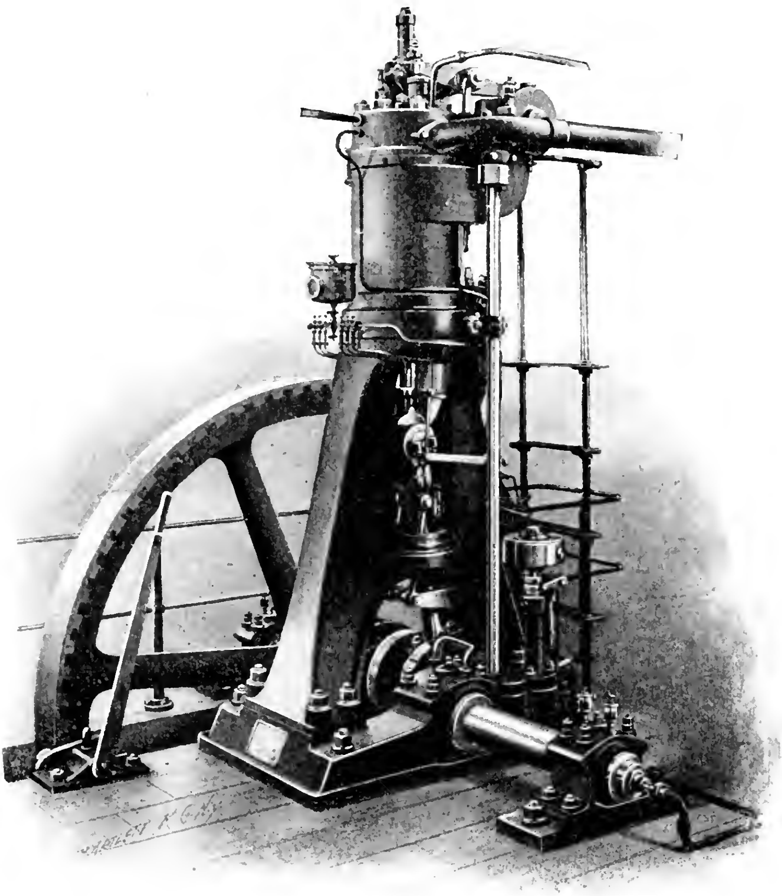

FIG. 1—Diesel Motor—Perspective View.

a strong base-plate supports the main journals of the crank-shaft, outboard bearings being provided for the shaft extensions which carry the fly-wheel and pulley. Bolted to the base-plate is a stout -A- frame containing the guides. In

the rear leg of this frame, a small air-pump is supported. On top of the frame is placed a cylinder open at bottom. Its top is closed by a head cast in one piece, in which are contained one suction valve for air, one discharge valve for spent gases, and a needle valve for the fuel. The admission to the casing of this fuel valve is controlled by a stop valve which can be instantly closed to shut off the supply of fuel. Besides this, there is a starting valve used only in starting the engine. Cylinder and air-pump are water jacketted. This water jacket was not used in the earlier experimental engines, but is found advantageous in keeping the temperature of the working parts uniform. As the temperature of combustion is so much lower than that of the explosion type of engines, a much smaller amount of water suffices for this. In the earlier German engines, the main shaft and crank are bored for water cooling. This, however, grew out of the practice of Krupp's Steel Works of boring all small shafts produced. The practice has been discarded in England and in America as unnecessary. The air-pump is driven by a set of levers attached to the main cross-head. Conveniently placed to one side is an air vessel, known as the starting tank, connected by copper pipe to the air-pump, and to the fuel valve casing.

The operation is as follows: On one down-stroke the main cylinder is completely filled with pure air, the next up-stroke compresses this to about 35 atmospheres, creating a temperature more than sufficient to ignite the fuel. At the beginning of the next down-stroke, the fuel valve opens, and the petroleum, atomized by passing through a spool of fine wire netting, is injected during a predetermined part of the stroke into this red-hot air, resulting in combustion controlled as to pressure and temperature. This injection is made possible by the air in the starting tank, which is kept by the small air-pump at a pressure some 5 to 10 atmospheres greater than that in the main cylinder. A small quantity of this air enters with the fuel charge, which it atomizes as described. When the motor is running at full load, a very small quantity of injected air suffices, and the pressure in the air tank steadily

rises. At half load, with less fuel injected, more air passes in. For this reason, the starting tank is made large enough to equalize these differences, and a small safety valve is provided on the air-pump.

The petroleum is pumped into the fuel valve casing by a small oil-pump bolted to the base-plate. This pump is arranged to pump a fixed maximum quantity of petroleum. A by-pass is provided so that this whole quantity, or any portion of it, can be returned to the supply tank. The governor controls the action of this by-pass valve, closing it just long enough to compel the exact quantity of the fuel required to pass into the fuel valve casing. As this requires only the movement of a small light wedge, the regulation is accomplished with great exactness. In this regulation resides a great advantage for the Diesel motor. The full charge of air being always supplied for complete combustion, it matters not whether the governor permits one or fifty drops of petroleum to enter the working cylinder at each motor stroke, the combustion is always complete. Thus variations in excess of air over that theoretically necessary, from 26 to 116 per cent. have been measured, and the analysis of the spent gases shows no trace of unburnt carbon or hydrogen. It is hard to conceive a more perfect combustion than that which takes place when fuel is sprayed, finely powdered or atomized into red-hot air, just beginning to expand. To stop the motor it is only necessary to close the valve which admits the petroleum into the fuel valve casing. The valve gear consists of a series of cams placed on a shaft journalled on brackets cast on the cylinder.

In starting the motor a hand-lever is pulled to one side throwing all these cams, except the exhaust valve cam, out of gear, and throwing a special cam into gear with the starting valve. A few strokes of the petroleum pump by a hand-lever inject a small quantity of petroleum into the fuel valve casing. The fly-wheel is thrown over by a lever a trifle beyond the upper dead point. The fuel throttle valve is opened, and, by a turn of the hand-wheel, communication is established between the air tank and the start-

ing valve. A single charge of highly compressed cold air enters the cylinder, sufficient to give two revolutions of the fly-wheel at moderate speed. At the close of the first revolution, the starting valve cam is automatically thrown out and the other cams into gear, thus on the second revolution, a full charge of air is drawn in and compressed, and in less than thirty seconds the motor is running at full speed.

It will be noted from Lord Kelvin's clear analysis of the working process of the Diesel engine, that Mr. Diesel makes a sharp distinction between the temperature of ignition and the temperature of combustion; the first is a constant value at each pressure and dependent only on the physical qualities of the fuel, the higher the pressure the lower the temperature of ignition. The temperature of combustion on the other hand is variable, depends on many conditions, and especially on the quality of the air by which the combustion is maintained, but it is always higher than the temperature of ignition.

Diesel's radical departure from all previous practice is in generating a combustion temperature by mechanical compression of pure air, utilizing this temperature to ignite the fuel, and by so introducing the fuel that the heat lost by expansion is practically balanced by the heat added by combustion.

Before the completion of this perfect engine, certain critics of Diesel's theories contended that the dimensions of the cylinder and all other working parts would become so great as to make it impracticable to build such engines. But in Diesel's engines, the increase and the decrease in pressures are so gradual, that there is no shock. The change from one to the other is always accomplished at a dead point. In all motors relying on explosion for their moving force, and even in the steam engine there is a direct blow at the moment of ignition or admission. I present here a drawing on which indicator diagrams of a high-pressure steam engine, of an explosion-type oil motor and of a Diesel motor, have been drawn based on the same piston displacement (*Fig. 2*).

Diesel's and the explosion-motor diagrams can be directly compared since both work on the four-stroke cycle. The steam-engine diagram should be quadrupled. This disposes of the objections just referred to.

These second and third diagrams (*Figs. 3* and *4*) are graphic comparisons of the Diesel motor with a number of

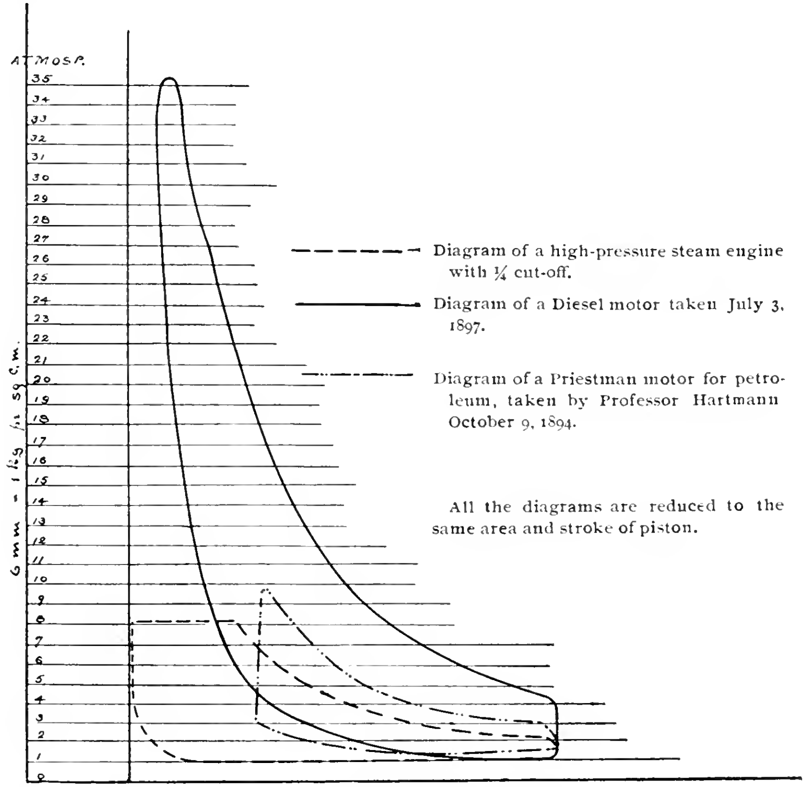


FIG. 2.—Comparison of diagram of a Diesel motor with diagram of a steam engine and of an explosion-motor.

the best petroleum motors as to economy in fuel and volume swept by the piston per second. They are given on the authority of Professor Hartmann, well-known as a careful and conscientious observer in this field.

The abscissæ represent piston displacement in liters per second, the ordinates petroleum consumption in grams per

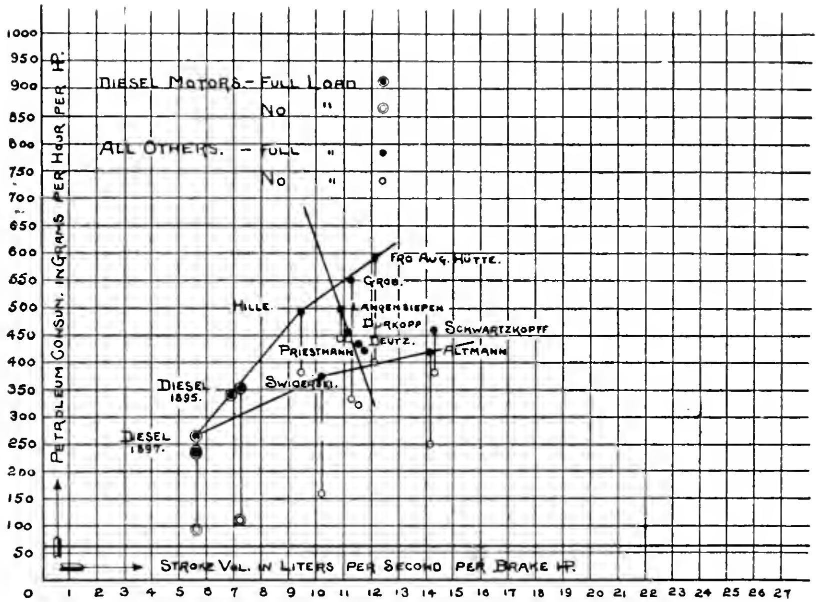


FIG. 3.—Graphic comparison of the performance of Diesel motors and best previous types of (explosion) oil motors.

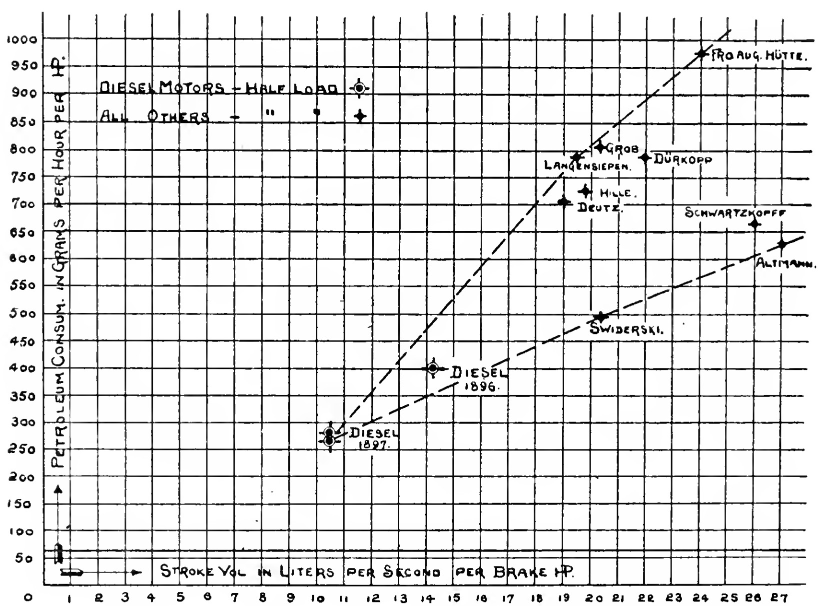


FIG. 4.—Graphic comparison of the performance of Diesel motors and best previous types of (explosion) oil motors.

hour, both figured on the effective or B.H.P. The full lines (*Fig. 3*) embrace the results for full load, the dotted lines (*Fig. 4*) those for half load. The comparison is between engines which burn ordinary safe lamp petroleum or kerosene; results obtained on benzine or naphtha are not considered, since motors depending on such dangerous fuels can never be generally adopted for industrial purposes. The calorific value of these highly inflammable and explosive liquids is no greater than that of safe kerosene or of fuel oil.

You will notice that we find the Diesel results in both cases near the apex of the angle. Or, plainly put, both at rated capacity and at half load the Diesel motor shows the smallest cylinder dimensions and the least expenditure of fuel.

Remember that the others represent the best results from engines carefully developed and improved in all mechanical details, while the Diesel motor is but the third one ever built, and that in its construction the practical realization of the theoretical cycle was the primal consideration, mechanical improvement being left for the future commercial exploitation of the machine.

Broadly speaking, the absolute efficiencies of the best-known heat engines of to-day range about as follows, taking into account actual calorific values of the fuel and effective or brake horse-power:

| | *Per cent.* |
|---|---|
| Small auxiliary steam engines, pumps, etc. | $\frac{6}{10}$ to 1 |
| Plain slide-valve engines in good condition | 3 to 5 |
| Single-cylinder Corliss engines | 6 |
| Compound-condensing engines | 8 |
| Reheating-compound or triple-expansion steam engines | 12 |
| Best oil engines (explosion type) | 16 |
| Best gas engines (explosion type) | 19 |
| Diesel motor | 28 to 30 |

All these are compared when running steadily at full load or rating at point of best economy.

But in a large majority of the applications of all these prime movers the exigencies of the service require them to be run frequently at three-quarters and at half load for a large part of their daily service.

It is conceded that in most engines the internal frictions or mechanical losses are a fixed amount, so that a loss of 15 per cent. at full load becomes 30 per cent. at half load. And thermal losses increase even more rapidly; for instance, in steam engines by cylinder condensation. In gas and oil engines the absolute efficiencies have in some cases shown a measured loss of nearly 60 per cent. In the Diesel motor the thermal efficiency is shown to increase with decreasing loads, thus counteracting in a marked degree the loss in mechanical efficiency which it shares with the other machines. From a number of carefully-checked tests, I found the average drop in absolute efficiency from full to half load to be only 12 to 13 per cent. in the Diesel motor.

So promptly and easily does it respond to a change of load, that a sudden addition of 30 per cent. to the electrical load on the Diesel motor at the Electrical Exposition at New York, by the throw of a switch, was not noticed by observers of the engine or the lights, though promptly registered by the ammeter.

For variable loads, then, the Diesel motor will show in practice a much greater superiority over all rivals than that apparent from the tabular figures just given.

The Diesel motor has been fully developed as an oil engine. At first it was tested only on ordinary lamp petroleum, such as is used in every household. But in November last I sent a barrel of American gas oil and four barrels of American fuel oil to Augsburg and Nürnberg, to make conclusive tests in regard to its reliability and economy on these cheap fuels. A series of tests was made, which gave the gratifying results that the economy was the same as on refined petroleum, and the combustion so complete that no fouling of cylinder, valves or exhaust-pipe occurred.

Encouraged by this, the German factories made tests with a cheap fuel oil, distilled from bituminous shale, and called "Solar Oil" in Germany. The result was so satisfactory that motors have since been sold guaranteed to run on these cheap oils, and they are doing this with perfect satisfaction.

American fuel oil is sold, delivered on track in tank cars

and tank wagons, at prices ranging from 1·6 cents to 2 cents per gallon in the West, and from $2\frac{1}{2}$ cents to 3 cents in the East; based on these prices, and allowing the high average of 240 grams per B.H.P. hour, a 100 horse-power Diesel motor will consume about 15 cents' worth of fuel per hour. With coal at \$2.80 per ton, the fuel cost per hour for 100 B.H.P. in a good steam engine will be about $54\frac{1}{2}$ cents for a slide valve, $43\frac{1}{2}$ cents for a Corliss, and 22·4 cents for a triple-expansion engine, and to this should be added a fair proportion of the fireman's wages, and for coal-passing and ash-hoisting, none of which charges would be incurred where the Diesel motor is used. Weighing all these facts, it becomes easy to understand the wonderful and unprecedented progress made by Diesel's invention in Europe.

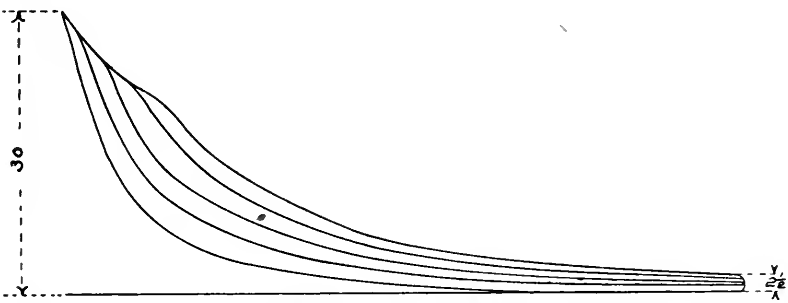


FIG. 5.—Diesel motor used with gas-indicator diagrams when regulating $\frac{1}{4}$ millimeter = 1 kilogram = 14·7 pounds.

Up to date he has licensed sixteen large machine shops to build his motor, and a conservative estimate of the amount of capital now specially devoted to this work in Europe places it at between four and five million dollars. The invention comes to our shores, not, as so many do, in its experimental stage, but in a complete form, so far as stationary motors are concerned. Designs for railway, street-car and marine motors have been made in Germany and England, and they will probably have passed through *their* experimental stage by the beginning of next year. The adaptation of the stationary motor to gas is practically completed, and a progressive series of tests on various kinds of gas will be run in Augsburg during the summer.

I take pleasure in presenting an enlarged view of an indicator diagram (*Fig. 5*) taken from the motor while running on Augsburg city gas, merely to show you that the same beautiful and economical cycle is possible with gas as with petroleum.

The work of experimenting, developing and testing has been performed with proverbial German thoroughness. American methods of manufacture with special tools, gauges and templates arranged to turn out a large number of duplicates of each size, will soon bring the motor into general use in the United States. To do this, the same broad policy of dividing the work among a limited number of first-class and well-equipped manufacturers, which works so well in Europe, will be adopted here.

The freedom from smoke, ashes, soot, etc., the absolute immunity against explosion, the great saving in space, in labor and in fuel, will soon bring this rational heat motor into general use in our large cities, at first for small and medium powers, but gradually for larger ones; and it is my opinion and firm belief that, before the end of the century, the name of Rudolf Diesel will be written on the same scroll with that of James Watt.

NEW YORK, May 18, 1898.

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# A TRIP TO RUSSIA AND THE URAL MOUNTAINS.*

BY GEORGE F. KUNZ.

[*Concluded from p. 214.*]

But, in addition to their metallic wealth, the Ural Mountains have for nearly two centuries been noted for their remarkable productions of gem-like minerals and gems that, for beauty and quantity, have given this region a foremost place in the mineralogical collections of the world.

In particular, the magnificent emeralds, alexandrites, phenacites, gigantic beryls, topazes, tourmalines, green garnets, amethysts, and the great variety of jaspers of all colors, are among those of the greatest interest.

*A lecture delivered before the Franklin Institute, April 20, 1898.

Catherine I, wife of Peter the Great, who named Ekaterinburg in her honor, first paid attention to the development of the precious-stone industry in the Urals; and two of the amethyst mines near Mursinka are to this day called Taljan, a corruption of Italian, she having sent two Italian lapidaries to this region for the purpose of developing the gem resources, founding the lapidary works and establishing an industry which gives employment to at least 1,000 people in this remote region at the present time.

The chief gem districts of the Urals are all within one hundred miles of Ekaterinburg, some eight or ten miles apart. In this limited territory there are over 100 mines or localities where minerals and gem stones of more or less value and great variety are extracted. The rocks comprise a number of kinds of granites, gneisses and related types, some of them quite peculiar, and are seamed and penetrated with granitic veins and dikes, giving evidence of great disturbance and frequent igneous intrusion. Among the more valuable gem minerals here found are sapphire corundum, in some cases of beautiful blue, occurring in a peculiar rock composed of corundum and orthoclase feldspar; topaz crystals, in cavities in true granite veins, with rich green amazon-stone and quartz crystals—a combination suggestive of some of our own Colorado localities; zircon, beryl, phenacite, and a host of other interesting minerals less familiar but sometimes very beautiful as specimens or ornamental stones, or valuable for economic uses in the arts.

The occurrence of the diamond in the Urals has for a long time been questioned. In a collection at Nijni Tagilsk I saw a small white crystal weighing $\frac{1}{3}$ of a carat, a twinned hexoctahedron, which was pronounced phenacite by a local mineralogist, who had taken its specific gravity; but which is, as the writer identified, a small opalescent white diamond, similar to those found at the Bagogem mine in Brazil. It was found in a small brook, near the village of Kalstchi. The existence .of pyrope garnets here, and their frequent finding, seems to sustain the theory of their origin, although some of the Russians are quite sure that the Russian who found the diamonds for Humboldt had really deceived him.

The admirable volume on the "Genesis of the Diamond," by the late H. Carvill Lewis, edited by Prof. J. T. Bonney, and the review of the same in *Science*, by the author, G. F. Kunz, fully discuss this subject, and in the Report of the United States Geological Survey, 1896.

At Kornilowog, and near the village of Chitanka, in the washing for gold, transparent corundum is found in the form of sapphires of pale blue color, also yellow, and rubies, light red, sometimes streaked with blue, resembling the Ceylonese rather than the Burmese, and green sapphires associated with fine ruby-red pyrope garnets, blue chalcedony, transparent zircon, quartz, etc. A ruby or sapphire worth $100 is of exceedingly rare occurrence, although many are found that sell for from 1 to 20 roubles each.

The emeralds, alexandrites and phenacites of the Urals are all from one small region, on the right bank of the Bolchoi Reft, a little north of Takowaja, fifty-one miles northeast of Ekaterinburg and quite apart from the other localities in Perm.

The emerald mines consist of four large groups of mines and a number of smaller workings; starting a little north of Takowaja, running north and west a distance of some seventeen wersts, or ten miles.

The Troitzk mine is about the central one of the group; the excavations are 1,000 feet in length and 200 feet in width, with shaft holes, wheels, etc., as the evidences of deep, extensive workings. These mines were operated by Pavlevsky, and also under the crown.

The Lubinsky mine, also a crown working, is two wersts north of Takowaja; the rock here is principally mica schist interspersed with actinolite and talcose schist. At the Krasnobolskaia, ten wersts south of Troitzk mine, the old shafts, drifts and workings indicate a vast amount of labor formerly carried on. This is the locality that has furnished the alexandrites and phenacites, as well as emeralds.

The Marienski emerald mines, seven wersts (five miles) north of Troitzk, are marked by several workings over 200 feet in diameter.

Among the associated minerals I observed quartz, feldspar, mica schist and chlorophane.

This is the chlorophane mentioned by Pallas, so highly phosphorescent and sensitive that it emitted light by the heat of the hand.

These mines were systematically operated fifty or sixty years ago, at an annual rental to the Government of 60,000 roubles ($45,000)—a charge which finally led to their abandonment, because the mining did not pay at so high a rental. Fine roads were laid to the great Siberian Street, twenty-one miles distant, and mining was conducted on an immense scale; for a distance of some ten miles along the course of the emerald veins, in a line running northeast and southwest, shafts were sunk and tunnels were driven in the talcose schist and mica slate in which were found the fine gems. Strange to say, although now these mines have not been worked for over forty years, and are carefully guarded by the imperial woodkeepers, we see from them to this day single gems for sale in Ekaterinburg, some of them valued at $300 each. It is hard to believe that these are from the original workings of the mine. Possibly they are sold by peasants, who have found them in re-working the old dumps, or who secretly work the mines when they are not watched.

Here also was first found the mineral phenacite, which received its name from *phenos*, meaning deceiver, and *lithos*, a stone, because it was long mistaken for white topaz. It is one of the most brilliant white gems known, but lacks the play of color possessed by the diamond. It was formerly found in connection with alexandrite, a chrome-green variety of chrysoberyl, which exhibits the property of changing from a green by daylight to a columbine or raspberry-red by artificial light. It was named alexandrite in honor of the Czar, Alexander II, by Nordenskiold, in 1842, who discovered it in the then famous emerald mines at Takowaja.

The alexandrites when cut as gems weigh from $\frac{1}{8}$ of a carat up to (very rarely) 5 carats each, though crystals and groups of crystals weighing 20 pounds have been found, so rare is it to obtain perfect pieces even in the large crystals.

About seventy-five localities (see map prepared by P. Kalugin, of Neviansk Savod) in the Government of Perm,

furnish gems or gem minerals. These are at present the property of the Czar, and are worked irregularly by the peasants, when their crops do not require attention.

Little has been done in any of the workings in the way of systematic mining, the method consisting generally in stripping off the rock, or simply following a vein with the use of as little timbering or pillar-building as possible. None of these mines show any great amount of work done; and from what I ascertained on my recent trip, the rights to mine may be offered for sale at a prohibitory figure, as was the case with the emerald mines, resulting in a complete suspension of the search for these minerals, whose finding, working into gems, and sale, furnished a livelihood to fully 1,000 peasants and lapidaries.

Here have been found marvellous crystals of transparent aquamarine, notably the one found on November 19 (December 1), 1828. This is a dark asparagus-green crystal, weighing 6½ pounds, brilliantly transparent, doubly terminated and beautifully marked with etched planes. It was acquired by the museum of the Imperial Mining Institute of St. Petersburg, and was then valued at 43,000 roubles, equalling at the present time $23,000.

At Lewaschinagorka, one mile east of Alabashka, there was found in 1888 a fine yellow crystal of beryl, 5 inches in length and weighing 8 ounces, of a beautiful golden color. Another beryl was found in the mountain of Zolotonah, near the village of Ujakova. This measured 5 inches in length, 2 inches in the widest part and $2\frac{1}{10}$ in its narrowest. It is doubly terminated, with a basal plane at one end, and with pyramidal faces at the other. It is a beautiful sea-green color and showing at the face the pyramid, a slightly fibrous structure is developed.

It weighs 436½ grams, almost 1 pound avoirdupois. Both these beryls are now in the remarkable collection of Russian minerals belonging to Harvard University.

Lewaschinagorka is about a mile east of Alabashka, in the Biserk (district) Alaraensky. A working, irregular in shape, 1,000 feet long and 40 to 50 feet deep, and 50 to 60 feet wide has been made here. It was at this locality

that the writer obtained the large yellow beryl crystal, now in the Garland Collection at Harvard University, was found. The rock here is pegmatite.

Black tourmaline occurs, plentifully interspersed in the orthoclase of all the gem-bearing veins of this district.

Beautiful blue, sea-green and white and sherry-colored topazes, generally transparent, are found at Alabashka and adjoining localities in Perm, some crystals weighing from a few ounces to 4 pounds each, notably a 4-pound one now in Harvard University, in the collection before referred to. There was a great yield in 1880 to 1882, producing many hundreds of crystals absolutely transparent and furnishing gems weighing over an ounce each, at Alabashka, which is situated on a small river of the same name. A number of excavations here have been made varying from 50 to 500 feet in length.

The famous red tourmalines—rubellites—formerly obtained from Chitanka and now from Sarapulka, and one or two other localities, are the most magnificent ever found as crystals, although they rarely afford gems.

At Sarapulka, in the Bizerk of Rejscheski, there are two localities, about 100 feet apart, on the side of a hill, which is one of a number, none of them higher than 100 feet, in a beautiful fertile rolling country. One of these mines was opened over a century ago; the other in 1841. At this place the excavations are now 150 feet wide, and at a depth of 30 feet a shaft is sunk in one of them. Numerous small workings are about it.

Perhaps the most magnificent gems from the Urals are the wonderful royal purple amethysts, changing to red by artificial light, that are found at about forty localities in the Government of Perm. For intensity of color and perfection of quality, and one might say majestic beauty, these rival almost any other colored gem. A series of them was exhibited at the World's Fair at Paris, in 1889, five of which were presented to the Czarina by the peasant who found them. Two of these measured nearly 2 inches across, and are royal purple by day, changing to rich red wine-color by artificial light, as do nearly all the Uralian amethysts.

Besides the purple quartz, or amethyst, other colored varieties of quartz occur, and mention may be made of the smoky shades, which may be altered by heat to rich deep yellow, forming the so-called quartz topazes.

M. Kleiner* says that the miners in the Government of Perm found that crystals of quartz and smoky quartz when taken from the ground and exposed to the air frequently became filled with rents, flaws and turbidity; but that if, immediately upon finding, the crystals were packed in damp sand or other material, and then put in a box and allowed to remain for one or more years in the cellars of their houses —which in the Urals are very warm—their color would not change as it did if exposed at once to the air. This is probably due to the fact that the crystals contain large quantities of liquid carbonic acid, and that at the temperature at which they are taken out, generally in spring or winter, the cavities would explode: whereas, by covering with sand, the same temperature they were found in was preserved.

Kleiner also states that to impart to the smoky quartz a golden yellow color, the peasants would put them in a loaf of bread and then bake them in the oven. When the color was not sufficiently changed, they were baked three or four times. He remarks, however, that the crystals often exploded before they changed color, which fact would substantiate the view that they exploded through the agency of the presence of carbonic acid gas that produced the turbid marking and rents on exposure to the low temperatures.

One of the most beautiful of all gems, and one that was not known two decades ago, is the demantoid (green garnet), or "Uralian emerald," erroneously extensively sold as olivine, found at Poldnewaja, near Syssersk, in the Government of Orenburg.

This form of garnet varies from yellowish-green to a most intense emerald-green, and possesses a high power of refracting light, showing a distinct fire like the diamond or zircon, so much so that in the evening it has almost the appearance of a green diamond. It is found as rounded nodules in a

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* Mineralogischer Verein von Russland, St. Petersburg, 1842.

curious serpentine-like rock, and also as loose grains in the gold washings, selling in small gems (the most desired) for almost the price of diamonds of the same size.

The rare mineralogical deep blue gem, euclase, has been found for the past forty years in the gold washings on the River Sanarka, associated with cyanite, for which it was at first mistaken. In 1889 superb sapphire-blue euclases, one a crystal 7½ centimeters long, were found here, one of which was cut into a gem of 4 carats, and sold for over $500.

Passing now from gems and precious stones to the ornamental stones for which Russia is justly celebrated, we note particularly rhodonite, malachite, jasper and lapis lazuli. The malachite of Nijni Tagilsk has been already referred to, and the use of this beautiful material in works of art is a peculiarly marked feature in the palaces and cathedrals of Russia, and in the Russian exhibits in all the great international expositions.

Lapis lazuli is found not so much in the Urals as farther east, in Siberia, in the neighborhood of Lake Baikal. From this far-off region has been brought the material used for veneering the celebrated lapis lazuli columns in the cathedral of St. Isaac's at St. Petersburg, and for many other elegant works of art in the imperial palaces.

Another of the most beautiful ornamental stones—labradorite or opalescent feldspar—is found at a locality in the Government of Kiev, where works for cutting it were founded in 1849 by the proprietor of the estate on which it occurred. This establishment was represented at the World's Fair by a number of articles. The yearly product is estimated at some $26,000, all made by handwork.

Rhodonite (silicate of manganese), in greater quantity and of finer color than anywhere else in the world, is found in the Ural Mountains, in the village of Sedelnikowja, thirteen miles southwest from Ekaterinburg, and at Malazidelinki, some eight miles farther. Its color varies from the richest deep warm pink to a reddish brown. Chemically, it is composed of silica and manganese; and it is almost always associated with pyrolusite and psilomelane, black oxides of manganese, which mark and streak the stone, frequently

adding greatly to its beauty. Its hardness is nearly 6·5, about that of the harder varieties of feldspar and of jade, although not so tough as the latter.

Nearly all the rhodonite of commerce is brought from this Russian locality, where it is found by the ton.

Pieces of fine pink color without the black streaks of oxide of manganese are exceptionally rare, so much so that when the late Empress of Russia, who was very fond of it, ordered, it is said, a piece cut the size and shape of an egg, that was to be free from all blemishes or black streaks, over one ton was cut for this purpose without obtaining enough for the desired piece.

Nowhere else in the world is jasper so abundant, and found in such endless varieties of color; it is obtained principally in the Government of Orenburg. One of the most highly prized colors is a rich gray-green; and also red, mottled with yellow and green, which form an endless series of combinations. It also is found in beautiful colors in the Guberline Mountains, near the city of Werchne Uralsk, 100 miles south of Zlatoust. A superb green jasper is obtained from the River Achtuba and from the River Ohra.

The jasper found in the Kalkansky Mountains, ninety-five miles from the city of Ohrsk, in the Urals, is of a gray to a grayish-green color, with a very fine-grained texture, and is an ideal substance for lapidary work. The most delicate touch of the wheel or graver is perceptible. The stone admits of a high polish, but the texture is so fine that a dull or mat surface is equally beautiful. It may be likened to a rich gray putty, on which the slightest touch of a razor-edge remains as a true impression. The contrasts between the polished and dull surfaces afford opportunity for very beautiful effects. This is one of the most highly prized of Russian ornamental stones.

I was present when a dish of Kalkansky jasper was presented by the city of Tscheliabinsk, in the Government of Orenburg, to the Czarevitch, on the second of August, 1891, at a reception given him at Troitzk (the first city out of the steppes), on his return from the great trip across Siberia.

This dish, which was 18 inches in diameter, represented a fluted platter, entirely covered with grape leaves, most of which were arranged or laid on so as to have the under or pale side up. At the edges, however, the leaves were turned up and over, so that in looking down on the dish the leaves all around the edge showed their bright upper side to a height of 2 inches, thus forming a border. The outer and upper edges, as well as the veinings on all the leaves, were polished, while the lower side of the leaves that was visible was dull. The grayish-green color of the Kalkansky jasper when unpolished exactly simulates the dull tint of a grape leaf. Several men were steadily employed for one whole year on this dish alone.

With this was also a small salt-cellar, similarly made of grape leaves, the stems of the leaves serving for feet, to carry out the ancient custom of presenting royalty with bread and salt on entering a city.

The Russian Czars have taken pains to develop the industries connected with these valuable and beautiful materials, and have founded great establishments for cutting and polishing ornamental stones, at which a kind and amount of work has been produced that is not equalled in the world. Chief among these are the Peterhoff Lapidary Works, at St. Petersburg, the immense establishment at Ekaterinburg, in the Urals, and the lapidary works at Kolivan, in Siberia.

Of these great Government workshops and their products, it is fitting that some account should be given here.

Many small and choice objects, as well as fine mosaic work of hard stone rivalling anything ever produced elsewhere, are made at the Peterhoff Lapidary building, established by Catherine II in 1775; situated between the new and old Peterhoff palaces, about forty minutes' ride from St. Petersburg. It is a three-story building with palatial interior decorations. The central hall is 150 feet square, and the entire building is an example of imperial magnificence. One is surprised to find marble staircases, marble floors, fine high ceilings, and the most elaborate machinery for stone-work. One floor is entirely filled with glass cases

containing stones to be worked up in the building. Here are expended annually 40,000 rubles, with sixty-four permanent and eleven temporary workmen.

The lapidary work of the Ural materials is all executed either at the Imperial Lapidary Works, at Ekaterinburg, or in the vicinity by the lapidary-masters, as they are termed, who employ the workmen or apprentices, each having his own peculiar style. The product of these latter is sold to the dealers at Ekaterinburg, who visit the Nijni Novgorod, Moscow and Ekaterinburg fairs.

The Czars have always manifested great interest in these lapidary works; and at Ekaterinburg is still on exhibition, preserved in a glass case, the cutting-tool used by the Emperor Alexander I, who worked here more or less, and became quite an expert lapidary.

A training-school connected with these works was started in 1877. At present there are fifty-five boys as pupils, who draw and design for nine months in the year, from nine to eleven o'clock, have one hour for recreation, and then model till two o'clock. The graduates have the option, either of remaining as lapidaries in the Government works, or of becoming master-workmen on their own account.

The lapidary works at Ekaterinburg, founded in 1765, and at Kolivan, in the heart of Siberia, in 1787, are so situated that they have command of an immense water-power by which they are run. These works are on a large scale, so that enormous masses of hard stone can be as readily worked as marble is throughout Europe. Those at Kolivan, in the Government of Tomsk, deal chiefly with stones from the Altai Mountains.

Many of the machines are of a primitive character, and have not been changed during the past century. But the facilities for sawing and for drilling of large columns, for ornamenting or for lightening large masses of stone, for channeling, grooving, polishing, etc., are ingenious, and are manipulated with the greatest skill. The annual product of these two establishments amounts to some $35,000, and is entirely for Government use, either in the palaces and public buildings, or for imperial gifts.

The various forms of lapidary work may be divided into three classes. First, the manufacture of vases, dishes and paperweights, often of large size, but invariably made of jasper, rhodonite, malachite, lapis lazuli, aventurine or the like. When the objects are of malachite or lapis lazuli, the body is made of slate or other readily-worked stone and then veneered with a thin coating of these more precious substances. Jewel-caskets, seals and small charms are made either plain or fluted, or are ornamented with leaves, scroll-work or other devices; also seals and cameo-work, such as animals and busts of prominent persons, as the reigning Czar, Turgenieff, etc.

Second, the manufacture of objects of a peculiar kind of mosaic work, somewhat in the Florentine style, and yet very different, made of such stones as perfectly simulate berries, fruits, leaves or flowers.

The unique feature which distinguishes this work is that while mosaics, properly so called, are flat and inlaid, here the objects are represented in their actual form and size. The favorite designs are fruit groups, which are so accurately matched in color and carved in form that they are exact reproductions in stone of the real fruits, resting upon a dish or pedestal of jasper or black marble. Thus, for raspberries, rhodonite of dark pink color is used: for red or black cherries, a peculiar colored sard and black onyx; for white currants, rock-crystal spheres, slightly smoky, which are cut hollow in the center, and the inner parts are so engraved as to simulate perfectly the seeds. The leaves are generally made of noble serpentine. For grapes, a peculiar colored sard, black onyx or dark purple amethyst is used: black onyx for blackberries, and a yellow jasper for mulberries; and these fruits are generally massed on pieces of jasper, or placed on jasper dishes, and are marvellous for their exactness as to the color, lustre and form of the natural fruit.

Third, the cutting of facetted stones for jewelry, such as aquamarine, sapphire, ruby, topaz and quartz of various colors, and the royal amethyst from Chitanka and Mursinka.

The Ekaterinburg Lapidary Works at present employ

seventy-five men, receiving 25 roubles per month each ($12.50), and ten boys at from 2 to 10 roubles each per month ($1 to $5). Forty thousand roubles are annually expended here.

In 1830 there were 150 men employed. All the designs for these works are made at Peterhoff. A wax model, the exact size of the object, is made by expert modellers and then handed to the lapidaries to copy. The original designs are returned to St. Petersburg, to remain secret in the cabinet of the Czar.

In August, 1891, there were at least 36,000 poods, or over 1,000,000 pounds, of rhodonite, jaspers of various colors, jade and other allied hard stones, at the Ekaterinburg Works. One single block of rhodonite weighed 1,500 poods, or 54,000 pounds. A mass of Kalkansky jasper weighed 500 poods (18,000 pounds). These may seem immense blocks of stone, but in 1869 a mass of rhodonite was brought to the Ekaterinburg Works weighing 2,850 poods (102,600 pounds). It was transported on immense sledges made of iron and wood, and was drawn by ninety horses, or, more strictly speaking, by thirty troikas tied together, one after the other. These were driven by more than fifty men, who shrieked, whistled, swore and beat the horses, and an entire week was required to transport the stone from the mine at the town of Sedelnikowja, about fourteen miles southwest, to Ekaterinburg, a rate of about two miles a day.

It is only on reaching the finishing-room of the great lapidary works that one realizes the imperial grandeur of what is accomplished here. A pair of magnificent Kalkansky jasper vases and pedestals, measuring six feet in height, occupied the time of half a dozen or more men for six whole years.

In 1840 there was finished a large elliptical jasper vase, now in the Winter Palace at St. Petersburg. It is one meter in diameter, and required just twenty-five years to complete. Time seems to be no object; there is no haste. Everything goes to the Czar, either for the adornment of his palaces or as imperial gifts; and whatever is not up to the standard is sold. The two imperial lapidary works are run at a cost of

80,000 to 100,000 roubles annually, paid from the private revenue of the Emperor.

One of the most remarkable pieces of lapidary work ever attempted is the sarcophagus of rhodonite now in process of making for the widow of the late Czar, Alexander II. The block weighs 800 poods, or 28,800 pounds. This may require at least ten years more to complete. A monument of green jasper was also made for her, which was brought from the Altai Mountains in Siberia.

These establishments have made Russia famous for wonderful objects of this kind, nearly all of which are of imperial character. Among the more notable of these may be mentioned the two vases of Siberian aventurine (oriental sunstone), a quartz containing brilliant spangles of mica, one of which was presented to Sir Roderick Murchison, and is now at the Royal School of Mines, in London, and the other to Alexander von Humboldt, and now in the Mineralogical Museum of the University of Berlin, in recognition of the services done by these two eminent scientists in their travels in the Urals.

Dishes, mantels, tables and other objects made of lapis lazuli and of malachite, are to be seen in the Louvre, at Petit Trianon, and at the royal palaces throughout Europe; and the celebrated columns veneered with lapis lazuli and malachite, over twenty feet high, at St. Isaac's Cathedral, and the immense dishes at the Ermitage and other palaces in St. Petersburg.

The Alexander Column was designed by Montferrand, in 1834, at the command of Emperor Nicolas I. This column, of polished red granite from Finland, is 82½ feet high, 13 feet 3 inches in diameter, and rests on a polished block of red Finland granite, 26½ feet square. It is surmounted by a bronze angel 13 feet high, holding a cross 10 feet high, and crushing a serpent underfoot.

In the porticoes of St. Isaac's Cathedral are over forty-eight polished columns of red Finland granite, 56 feet high and 6·6 feet in diameter, resting on immense steps of polished granite, each of a single piece.

The west entrance of the Ermitage is supported by eight

pilasters, against each of which leans a dark-gray granite polished figure from Sserdobol. Each pilaster is 19·8 feet high, supporting the roof. These are only a suggestion to the wonderful interior,—one hundred and twenty columns, all of which are of marble, granite, jasper or other costly material.

On the Anitschkow Bridge over the Fontanka Canal, St. Petersburg, are four colossal bronze horses after the models of Baron Klodt, of St. Petersburg.

From a careful examination of the Russian gem minerals, namely, amethyst, ruby, sapphire, beryl, tourmaline, colored topaz, chrysoberyl, alexandrite, etc., it is my conviction that they suggest an identity of occurrence in the crystalline rocks with those of Ceylon, Japan and Madagascar, and of Oxford County, Maine.

The finest collections of Russian minerals are in the Imperial Mining School, in the Imperial Academy of Science, and the Kotchubey Collection in St. Petersburg, the Kokscharow Collection in the British Museum, the Duke of Leuchtenberg Collection in the Mineralogisches Institute at Munich; and, in the United States, in the collections of Harvard College, Cambridge, Mass., the Field Columbian Museum, Chicago, that of Mr. Clarence S. Bement, and the late W. S. Vaux and Mr. George Vaux, of Philadelphia; also in the American Museum of Natural History, and the School of Mines Collection, New York, and in the National Museum at Washington, D. C.

Finally, a few words may be said as to recent archæological investigations in the Ural region, a great district about which there is yet much to learn; and, although its mines and minerals have been studied so well as to make the memoirs upon them classics for the entire world, the archæology and anthropology are not so thoroughly known.

The low water in the Ural region during the summers of 1890 and 1891 afforded an unusual opportunity of examining the lake and river bottoms of this district. This was improved by the Uralian archæologist, Prof. C. Clerc, my esteemed friend and adviser, who accompanied and guided me on my trip with untiring devotion and courtesy, who

has done much to advance the sciences in the Ural Mountains, and to whom I would here express my sincere thanks. His explorations resulted in the finding of some 60,000 objects in flint, jasper and other stones, some of them evidently of high antiquity. The study of these will probably give us valuable data as to the history of the region from an early date to the present time.

On the crest of a small hill, a couple of miles east of Ekaterinburg, are some very curious and interesting prehistoric localities, known as the Kamennya-palatki, or Stone Tents. These are elevated masses of the stratified granitic rock composing the hill, which have in some manner resisted weathering more than the rest, and now stand out on the summit like low towers or beehive-shaped huts. Their general form, and the strongly-marked horizontal layers of the weathered granite composing them, give them the aspect of half-ruined structures built by man. A few years ago a person seeking for gold or treasure discovered at the base of these "Stone Tents" some remains of ornamented pottery; this led to careful examination by archæologists: and there have since been obtained, beneath, around and on the top of them, many interesting objects, indicating that these singular natural formations were a favorite resort of men in prehistoric times. Dr. Clerc, who has written and published largely in regard to them, suggests that they may have been used partly as places of sacrifice and partly as lookouts or watch-towers. He even inclines to the belief that man has aided nature somewhat in shaping them into their peculiar forms. The objects found include ornamented pottery, stone implements, a rock-crystal bead and fragments of bones. The further discovery of a small bronze arrowhead in the vicinity, associated with remains otherwise similar, leads M. Clerc, with M. Malakhoff and others, to assign the whole to the close of the neolithic period, when bronze, although known, was still rare and valuable. Other similar natural structures, some of larger size, occur at several points in this region, and have yielded similar traces of having been long frequented for some purpose by prehistoric men.

# Mining and Metallurgical Section.

*Stated Meeting, May 11, 1898.*

## OLD AND NEW METHODS APPLIED IN PLANNING PIPE-LINES AND PENSTOCKS.

BY F. M. F. CAZIN, Hoboken, N. J.,
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[*Concluded from p. 192.*]

It being known that $H'' < H' < H$, there must be an inversely proportional relation between values in which these values $H''$, $H'$ and $H$ take the place as divisors. Hence,

$$\sqrt[4]{\frac{h}{H''}} > \sqrt[4]{\frac{h}{H'}} > \sqrt[4]{\frac{h}{H}},$$

and in consequence $D'' > D' > D$.

This result may be expressed in words as follows:

II. *The diameters of the pipes, at any level of the supply-pipe line, may* (in order to permit the body of water to descend at uniform rate through the entire length of the pipe, or to descend in unimpeded adaptation of its shape to the laws of gravitation) *be decreased at the rate of the fourth root of the head above such level increases, the required diameter being in all cases as*

$$D = d'' \cdot \frac{\sqrt[4]{h'}}{\sqrt{H'}}$$

It may then be mentioned that, whenever there is in a pipe-line an upward bend, by which the head, and consequently the velocity of movement, is intermediately decreased, the upward bend requires an increase of diameter, as the increase of head admits of a decrease of diameter. (See *Fig. 2.*)

In the form of the equation that contains the coefficients $h$ and $H$, heads, in fact, are exclusively considered, and no

doubt remains as to what these values stand for; but in the form of the equation that contains $v$ and $V$ as coefficients, doubt may exist whether velocity in fact and as experimentally ascertained be meant, or theoretical velocity under any surveyed head be intended.

It therefore appeared as preferable to express the stated law on the basis of the undoubtful values $h$ and $H$ for surveyed heads as conditional to theoretical requirement.

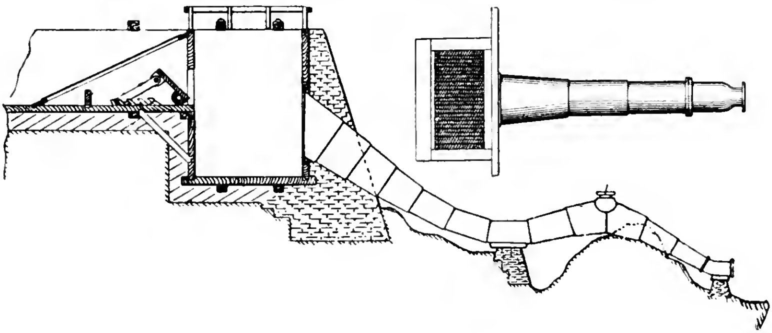

FIG. 2.

*The diameters of pipes and of their inlets, at any vertical distance below the surface of the entering liquid, as required for imparting to them sufficient width for permitting a stated volume, weight or body of liquid to fall in the shape that it would assume if free to fall in adaptation to the laws of gravitation.*

III. *The orifice of a supply-pipe, intended to eject a circular current of a diameter d inches, under a head of h feet, which orifice is at a vertical distance of H feet, below the surface of the inflowing liquid, to permit inflow in the same quantity, as will, with unimpeded flow, be ejected, must be as*

$$D'' \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H''}}$$

IV. *The diameter of a supply-pipe at any level, intermediate between the level of ejection and the surface of the supply-liquid, to secure unimpeded flow under the laws of gravitation, must be as*

$$D \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

*when $H$ feet is the difference in feet in level between the surface of inflowing supply and the level of $D$, and $h$ in feet is the total head, under which ejection takes place from an aperture of the diameter $d$ inches.*

V. *To permit natural flow within a supply-pipe, it must, at any level above that of final ejection, have a diameter equal to*

$$D \text{ inches} = d \text{ inches} \cdot \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

*when $d$ is the diameter of the aperture of ejection, $h$ in feet the total head to ejection, and $H$ in feet the head above the location of the diameter $D$.*

In the preceding discussion the vertical distance between the level of ejection and the level, where the diameter $D$ is to be located, has not been considered. When $h$, $D$ and $d$ are known, it may be desirable to locate the position of $D$, between the surface of supply and the level of ejection. If the so far undiscussed distance be signified by $H°$, we know that $H° = h - H$, and in consequence, that $h = H° + H$.

The general equation may, therefore, be expressed in the equivalents for

$$D = d \cdot \sqrt[4]{\frac{h}{H}} = d \cdot \sqrt[4]{\frac{H° + H}{H}} = d \cdot \sqrt[4]{\frac{H°}{H} + 1} = d \cdot \sqrt[4]{\frac{h}{h - H°}}$$

and $$\left(\frac{D}{d}\right)^4 = \frac{h}{H} = \frac{H° + H}{H} = \frac{H°}{H} + 1 = \frac{h}{h - H°}$$

and $$H = \frac{h}{\left(\frac{D}{d}\right)^4} = \frac{H° + 1}{\left(\frac{D}{d}\right)^4}$$

and $$H° = h - \frac{h}{\left(\frac{D}{d}\right)^4}$$

Therefore $d$, $D$ and $h$ being known, the location of $D$ may be ascertained by determining the values for $H$ and $H°$.

Other investigators have approached the problem that has been discussed in the preceding lines on exclusively empirical lines.

They have experimented with supply-pipes and have compared theoretical efficiency with the results of their observations.

All of moment that has been achieved in this empirical line of research has been collected in an interesting and meritorious little volume: Tables, showing *loss of head*, due to *friction* of water in pipes, by Edmund B. Weston, C.E. (N. Y., 1896.)

The real contents of the volume would have been stated on the title in a manner more to the point, if it read: *Loss of head due to friction and to the orifice of influx*, because the tables, without exception, show a total loss, attributed to the two different causes of *friction* and *orifice*. The collection of experimental data and their arrangement by Weston being admittedly a correct and full statement of observed facts, *the by me formulated laws*, as hereinabove stated, *must either stand in harmony with these observations, or if in conflict with the facts, as observed, they must fall as chimerical before the authority of such facts.*

It would not do, in connection with a law deduced from the very nature of things, to claim "that the same formula would not apply to all cases," notwithstanding the fact that Weston advances such a claim, for all that, which the science of hydraulics has offered up to date towards solving the question under investigation. Weston frankly admits (page III) that "a general formula was not discovered which would satisfactorily apply." *He, nevertheless, quotes three different equations and declares them as normally applying to three different modifications of solid faces on which the liquid slides. Two of these equations originated with the French savant, H. Darcy, and the third one with Weston himself.

Weston's formula, applicable to smooth pipes, and to pipes that do not exceed 3·5 inches in diameter, is as follows:

* Blaine, R. G., *Hydraulic Machinery*, 1897, p. 54: "Sufficient data for accurately determining the flow of water in large pipes are not yet available. It is best to allow a margin for excessive friction and to guard against repeating such an expensive mistake as that made recently at Newark (East Jersey Water Co.), where about 21 miles of riveted steel mains have to be duplicated."

$$H = \left(0{\cdot}0126 + \frac{0{\cdot}0315 - d \,.\, 006}{1 \quad v}\right) \,.\, \frac{l}{d} \,.\, h$$

in which formula $d$, $h$ and $v$ are used as commonly used, $l$ designating the length of pipe in feet, and $H$ the loss of head in feet, due to friction.

The other loss of head, *due to influx*, is stated by Weston to be correctly stated by a reducing coefficient = 0·505.

Empirical investigation has been conducted on the very fundamental assumption that a pipe only of many times the diameter of the aperture of ejection be fit to feed such ejection in such quantity that the discharge represent a full benefit of the actual head. Pipes discharging from an aperture of their own uniform size showed a loss of efficiency, or, as commonly called, of head, which loss amounted all the way from 90 per cent. to many times the theoretical effect of the head in fact.

So far, it has occurred to nobody, except to myself, to inquire into the conditions of free and unimpeded fall and flow of liquids in pipes, and engineering practice in this matter contented itself with testing efficiencies, the same as the English Admiralty contented itself in matters of nautical construction with testing the resistance to models of men-of-war, until a law for measuring such resistance, by the simple means of the quotient of the length in metres on the ship's water-line in the displaced weight was discovered by the author. (Compare the *Journal of the Franklin Institute*, March to May, 1893.)

Setting aside the placid submission to an experienced evil, the author's inquiry has been directed to an obviation of the same and to the avoidance of using unnecessary and excessive sizes of pipes.

Even Rankine has never abandoned the older views as stated. In his latest supplementary statements he yet (to Article 646) states: "The loss of head, due to the resistance to the flow of water in a pipe, arises mainly from friction." There is no mention of resistance consequent to the shape of pipe, forcing the water to flow in another shape than the one that it would and must assume, if free to so do, under the eternal laws of gravitation.

The nearest approach to a progressive conception of the problem in hand may be found in Rankine's statement (same supplement) that if the form of the mouth-piece be that of the *contracted vein*, the resistance at entrance of pipe be insensible. But in his explanation of that, which he refers to as "contracted vein" (Article 627), he does not, as I do, stipulate any law by which the shape of mouth-piece as well as pipe may be determined, but refers to an entirely different point of consideration, namely, the contraction of a free jet, after leaving the aperture of ejection, as discussed by Poncelet and Lesbros, on an exclusively empirical basis, the same as that on which the entire question, now under consideration, has invariably been treated.

While in Weston's tables the *loss* of head, due to *orifice of influx*, is invariably stated, as equal to 0·505 . $h$, the *loss* attributed to *friction* on pipe-walls appears as averaging in excess of 0·4 . $h$, while the total average of losses appears as 90·557 per cent. of head.

We also find in Weston's book the assertion repeated, that "friction is directly and simply as length." Up to date, this proposition has been understood to the effect that the increase in length of a supply-pipe called for a proportionate increase of width. The more rational interpretation, as supported by the new method of dealing with the problem, is evidently to the effect that provision for counteracting the effect of friction should extend over the entire length of the pipe. On this more rational interpretation my proposition for a lubricating liquid shell is based, the execution of which must of necessity take shape in an increasing stable coefficient to the diameter $D$ on the entire length of pipe, the amount of which coefficient will have to be established by virtue of prevailing conditions, and will be discussed here below.

With an understanding about the variance in conception, as submitted in the preceding lines, we are prepared to test the new proposition by the results of observation, as collected by Weston.

The *loss* of head in feet, due to the *orifice of influx*, has been assumed in Weston's Tables, as already stated, as of uniform value, namely as 0·505 of the head.

The *loss* of head in feet, due to *friction* is stated, amongst others, as follows:

In pipes of $\frac{1}{2}$-inch diameter as—

| | | | | | | |
|---|---|---|---|---|---|---|
| Loss | $\frac{1.0352}{2.03}$ | $\frac{1.9725}{4.15}$ | $\frac{2.7548}{5.98}$ | $\frac{3.633}{8.14}$ | $\frac{4.4048}{9.97}$ | $\frac{15.7335}{39.26}$ |
| Head | | | | | | |

to which fractions the following figures are equivalents:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Loss | 0·51, | 0·475, | 0·46, | 0·446, | 0·442, | 0·4, | to which must be added as loss in inlet— |
| Head | 0·505 | 0·505 | 0·505 | 0·505 | 0·505 | 0·505 | |
| Total loss | 1·015 | 0·980 | 0·965 | 0·951 | 0·947 | 0·905 | |

The loss attributed to *friction* averages in the six quoted cases as 0·4555, and the general average of losses is, in consequence, as 0·9605 . *H.*

Applying the newer conception to these cases, the inquiry would be directed first towards finding the dimensions of the orifice of influx that would permit to a 2-inch aperture of ejection the full benefit of head, as against the older conception, ascertaining the loss resulting from uniform size of inlet and pipe, which amounts to 0·505 . *H.*

A precise answer is given to this inquiry under the newer method, to the effect that the requirement in diameter of orifice of influx is absolutely dependent on the head above such orifice, as no influx can take place without such head, and that the lower such head, the wider the orifice should be. A precise answer can only be given when a precise head above such orifice is assumed.

The equation for *D*, when the value for *H* be as *O*, reads

$$D = \sqrt[4]{\frac{h}{O}} \times d$$

a product in which one factor is of unlimited greatness.

The true interpretation of this result is two-fold, namely:

(1) No orifice of inlet suffices between which and the supply-surface there is no difference of level.

(2) The equation gives evidence of its own validity, even though the case may pass out of the realm of elementary mathematics.

Assuming the said head to be 1 foot $= H''$, then

$$D'' = d \cdot \sqrt[4]{\frac{h}{H''}} = d \cdot \sqrt[4]{\frac{h}{1}} = d \cdot \sqrt[4]{h}$$

Selecting one of the cases coming nearest to the average of general loss, say the fourth in the row, as quoted, the applied equation reads:

$$D'' = 0{\cdot}5'' \cdot \sqrt[4]{8{\cdot}14} = 0{\cdot}5'' \cdot 1{\cdot}69 = 0{\cdot}845''$$

The relation between area of actual to required orifice then appears as $0{\cdot}5^2 \div 0{\cdot}845^2 = 0{\cdot}25 \div 0{\cdot}714$, the actual area being only

$$\frac{0{\cdot}25}{0{\cdot}714} = 0{\cdot}35$$

and the loss being in the case as assumed as $1 - 0{\cdot}35 = 0{\cdot}65$, in place of 0·505 as assumed by Weston.

But assuming the orifice of influx to be 2 feet below the surface of the supply, then the required diameter of orifice appears as

$$D' = d \cdot \sqrt[4]{\frac{h}{H^1}} = 0{\cdot}5'' \cdot \sqrt[4]{\frac{8{\cdot}14}{2}} = 0{\cdot}5 \cdot \sqrt[4]{4{\cdot}07} = 0{\cdot}7102$$

The proportion between areas then appears as:

$0{\cdot}5^2 \div 0{\cdot}7102^2 = 0{\cdot}25 \div 0{\cdot}5044$, the actual area being only

$$\frac{0{\cdot}25}{0{\cdot}5044} = 0{\cdot}495$$

and the *loss* due to *orifice of influx* appears as $1 - 0{\cdot}495 = 0{\cdot}505$, or precisely the same as Weston states it, as the observed result of many tests. Pity it is that the experimenter has not stated the head above orifice, which statement would have furnished still further experimental corroboration for my new conception of the problem of adapting the dimensions of pipe-lines to the conditions as given by head and quantity of discharge demanded.

It now remains to also compare the empirical results concerning loss of efficiency in pipes, collected in Weston's Tables, and attributed to *friction*, with the results obtainable by means of the laws as hereinabove evolved and pronounced.

These laws would meet neither doubt nor contradiction on the part of hydraulicians, were it not for that ominous word "*friction.*" The main destiny of the word has been to confuse observations and conceptions, which without its use might have been precise and clear. No other word in technics and science has served as a symbol of misconception to the same degree as this word "friction" has. And never has misconception been adhered to with firmer tenacity than the misconception of friction. It is, nevertheless, inopportune to largely discuss this question of friction, and even as a matter of convenience, I propose on this occasion to be content with discussing the antidote of friction, namely, lubrication, in connection with water flowing in pipes. (Compare "Resistance to Ship's Motion," by the same author, *Journal of the Franklin Institute*, March, 1893, page 205, etc.)

Having ascertained what space a falling body of water requires for its unimpeded fall within pipe-lines, the author proposes to surround the falling body with a lubricating shell of water that does not fall. Water will then move within water, and the friction will not be in excess of what it is when a smaller current moves within a larger body of water. Prony, the inventor of a friction-dynamometer, which has contributed more than any other cause to discrediting the prevailing conception of friction, has established an empirical coefficient of loss for such inter-liquid friction, applicable to natural velocity (compare Rankine, Manual, Art. 640) as

$$\frac{v + 7{\cdot}71}{v + 10{\cdot}25}$$

If Prony's estimate of such effect of inter-liquid friction were correct, it would evidently be applicable inversely in increasing the diameter of pipes, based on the velocity of the liquid; and in place of

$$D = d \, . \, \frac{\sqrt{v}}{\sqrt{V}} = d \, . \, \frac{\sqrt[4]{h}}{\sqrt[4]{H}}$$

the equation for diameter should read as

$$D = \frac{\sqrt{v + 10{\cdot}25}}{\sqrt{V + 7{\cdot}71}} = \frac{\sqrt[4]{h + 10{\cdot}25^2}}{\sqrt[4]{H + 7{\cdot}71^2}}$$

Modern conception of correct measurement of friction excludes the velocity of motion in contact-faces as an element in such measurement, and considers weight and its expression: pressure, as the main element in such measurement. In the case under consideration the constantly increasing velocity is a direct expression of the effect of weight, when free to fall, and is the only expression in the equation that represents weight.

Therefore, as far as the modern conception of friction is concerned, the application of a corrective in the shape of inversed effect of friction, to the value of current-area or of current-diameter of section, could not be objected to. Nevertheless, such corrective in the form proposed by Prony is absolutely inapplicable, because it inevitably leads to absurd and impossible results, as any calculation based thereon will demonstrate.

In this connection it may be opportune to also quote Rankine's expressions (Art. 639), as follows:

"The friction of a stream against its channel 'causes' not merely retarding of the film of fluid, which is immediately in contact with the sides of the channel, but a retarding of the whole stream, so as to reduce its motion to one approximating to a motion in plain layers, perpendicular to the axis of channel."

Although this effect, as by Rankine described, is in fact and precisely the effect of impeded formation of the liquid body in its descent, such as adaptation to the laws of gravitation would produce it, he had not in mind such real cause of the described effect, namely, the enforcement of a uniform velocity of fall in pipes of uniform size, and the consequent formation of horizontal layers, as against the natural velocity, that increases at the rate of the square of the distance of fall, and its effect of contracting the falling liquid body as fall proceeds.

The admission by Rankine (Art. 625), that "single layers move with uniform velocity," is equivalent to the admission by the celebrated scientist, though inadvertently, that a retarding effect, otherwise attributed to friction, may more correctly be attributed to the resistance offered to the

motion of the liquid by a form of channel, which is not in full adaptation to the form assumed by the liquid body under the laws of gravitation, as the consequence of continuously changing natural velocity. That *in a pipe of uniform section but one velocity can prevail from end to end* is a natural conclusion from the generally accepted condition of cross-current layers moving with uniform velocity. This then means, in fact, that in pipes of uniform section the liquid body is forced to fall with uniform in place of increasing velocity, and in consequence forced to undergo inter-liquid friction between all of its parts, while with a channel adapted to the natural requirement, as established by the lengthening of body under increased velocity, the body that changes position within a second for the distance, as indicated by velocity, being considered as the moving body ($= Q\,y$), such interior friction is not one that resists to gravitation, but is in harmony with the effect of gravitation, and in consequence reduced to a minimum. Obviating excess of interior friction, there remains only the friction against the walls of the channel, and as in pipes of excessive width throughout, a shell of water may perform the function of a lubricator to a falling liquid body that has sufficient space to develop and fall in its natural shape. To establish the diametrical requirements, therefore, is equivalent to the finding of the limit (*justemilieu*) between excess and deficiency in size of supply-pipes intended for a given capacity.

In the preceding lines it has been demonstrated, in regard to *loss of head* attributed to *orifice of influx*, how closely the results of the newly-proposed equations for determining the diameter of such orifice coincide with the facts as collected in Weston's Tables. It is immaterial to which part of these tables the new equations be applied; the same results, when properly applied, will be evolved. To repeat these calculative tests would unnecessarily intrude on the valuable space of this publication. But it remains to repeat the same demonstration in regard to the *loss of head* attributed to the effect of *friction* within the pipes or against their walls. In such renewed demonstra-

tion it will be most to the point to follow out the same case as considered in regard to loss in orifice of influx.

We have had under consideration a pipe of uniform ½-inch diameter, ejecting under head of 8·14 feet. We have in regard thereto established the necessity of a 3-inch orifice of influx, if situate 2 feet below surface, in order to secure the possible ejection of the maximum quantity that may be ejected from the ½-inch aperture under the stated head.

We may now assume that the orifice of 3-inch diameter be contracted to the ½-inch uniform diameter of the pipe at a vertical distance below of 6 inches. And we may inquire into the effect of such contraction.

The head above such contraction is as $2' + 0{\cdot}5' = 2{\cdot}5' = H$. The head above the level of ejection is $8{\cdot}14 = h$.

The required diameter ($D$) to permit unimpeded motion of liquid body, as ejected per second from the stated aperture under the stated head, is shown by the equation:

$$D = \sqrt[4]{\frac{h}{H}} \,.\, d'' = \sqrt[4]{\frac{8{\cdot}14}{2{\cdot}5}} \,.\, 0{\cdot}5'' = 0{\cdot}672$$

We then have the proportions of real to required section as

$$\frac{0{\cdot}5^2}{0{\cdot}672^2} = \frac{0{\cdot}25}{0{\cdot}45} = 0{\cdot}55$$

And the loss of effect is as $1 - 0{\cdot}55555. = 0{\cdot}44444.$

We find in Weston's Tables this loss within pipe stated as amounting to 0·446, the difference, inappreciably small as it is, being attributable to neglect of decimals.

It seems to be entirely superfluous to carry the demonstration any further. What has been shown appears to be sufficient to convince us of the fact that the loss attributed to friction and to orifice of influx is really a loss consequent to the same cause, namely, the lack of space in a pipe of uniform section, for the free development of form of falling liquid body, as it would assume, under the laws of gravitation, if its movement were unimpeded, and that such loss can presumably be obviated by adapting the form of supply-pipes to the dictation of nature, viz.: under the equations as hereinabove developed.

While the loss attributed to friction is not, as such, so attributable, it is wise to provide against any minor loss so attributable.

Whenever the diameter of penstock or pipe-line is in excess, on their entire length, of that which the unimpeded movement of the liquid body demands, then such excess provides for the liquid lubricating shell, as hereinabove mentioned. Such excess assumes the form of an increasing coefficient to the value of the rational pipe diameter; and experiments have demonstrated the fact that in available sizes such a coefficient = 1·1. covers the requirement when applied to pipes that have the rational diameters as conditioned in the stated equations, which will then read:

$$D''' = 1 \cdot 1 . . \sqrt[4]{\frac{h \text{ feet}}{H \text{ feet}}} . d''$$

$H$ signifying the head above the level of $D$, and $h$ signifying the head above the level of ejection.

The only variable value in the equation is the coefficient 1·1, which may find closer adaptation to qualities of interior pipe wall, though within very narrow limits only, on penalty of permitting excess in size over and above practical requirement.

Nought of importance remains but to speak of the practical economy or saving in first cost resulting from planning penstock and pipe-lines under the more modern conception of the problem, viz.: by the stated equations, whenever the required discharge per second or the section of total ejectable current and the available head are known.

It is evident, from the very figures as shown, that, for a specified discharge, we find, on the one hand, the necessity, when using pipes of uniform section, to provide for losses in efficiency, amounting to from 90 per cent. to many times the total maximum efficiency of a pipe of the same section as that of the aperture of ejection. In consequence, we are compelled to use pipes the size of which, from end to end, is largely in excess of that which is needed. On the other hand, we find in the author's newer devices, first invented to meet a practical requirement, and as such protected by

granted patent-right, and later on proven correct by mathematical evolution, that we can economize in first outlay to the extent of a major part by adapting successive sizes inversely to increasing velocity of fall, or to the real nature of the requirement. The illustrations are intended to indicate the new device. Specific estimates of comparative costs will be published on a later date.

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*Stated Meeting, April 13, 1898.*

# THE REDUCTION WORKS FOR SILVER ORES AT ADUANA, SONORA, MEXICO.

By Miltiades Th. Armas,
Formerly Assistant Superintendent.

The Quintera Mine of the Alamos district in Sonora, is a powerful silver-bearing lode, known as the "Quintera" lode, and to-day is the only one in that section of the country which, notwithstanding the complexity of the ore, is worked profitably.

With a general course nearly due north and south, and a dip of 16° from the vertical towards the west, this lode traverses the crest of the Quintera Mountain.

Flanked east and west by higher and more rugged peaks, this mountain forms the divide, or pass, over which a bridle path connects the mining towns of the two leading mines, viz., Aduana on the northern side, where the reduction works of the Quintera Mine are situated, and Promontorios on the opposide side, with the reduction works of the Almada and Tirito mines.

The population of Aduana, Promontorios and the neighboring settlement of "Minas Nuevas" is made up of native Mexicans mostly of Indian blood.

Besides being very docile, they become excellent mine and mill operatives. The pure-blooded Indians appear to me to be the best of all.

In this part of Mexico its cheapness goes far toward off-

setting the evils which may be considered to attend the pursuit of mining or milling by foreigners.

Six miles from Aduana is Alamos. This is one of the most important towns in Sonora, and is connected with Aduana by a wagon road, which continues seventy miles to the port of Agiabampo, on the Gulf of California.

This brief geographical description, with some additional information concerning the system of weights and mode of transportation, will probably render clearer the description of the various methods applied at the reduction works of silver ores in Aduana.

Notwithstanding the adoption of the metric system by the Mexican Government, in all its official transactions, the people at large still adhere to the old Spanish measures.

In mining districts the unit is 300 pounds (1 pound = 460 grams), or the weight that a mule can carry comfortably, since the principal means for transportation is by mules.

The natives speak, as a rule, of so many ounces per cargo of 300 pounds. (1 ounce = 28·76539 grams.)

A description of the divers kinds of ore obtained from the same lode, with an average composition of each kind, will now be considered.

The admixture of ore is complex and varies in quality according to the relative proportions of its several minerals. All is hand-picked and hammer-dressed, and assorted into several grades, according to the degree of concentration of its metalliferous contents, or to the predominance of certain ingredients. This work is done at the mine by boys called "pintistas."

*Smelting Ores.—A.* Argentiferous gray copper, carrying some blende and galena. The practical yield in silver of ores of this class is from 350 to 600 ounces per ton.

ANALYSIS.

| | Per Cent. |
|---|---|
| $SiO_2$ | 36·2 |
| Cu | 11·4 |
| Pb | 9·8 |
| CaO | 1·8 |
| Fe | 2·1 |
| S | 10·8 |

| | Per Cent. |
|---|---|
| Zn | 11·5 |
| Sb | 6·3 |
| As | 5·2 |
| $As_2O_3$ | 1·2 |
| Ag | 2·4 |

*B. Black Ore—Priets II.*—A complex variety, made up of galena, blende, copper glance, chalcopyrite, with arsenical and antimonial sulphides, all more or less argentiferous, and containing occasionally some stephanite. Their yield in silver is from 200 to 400 ounces per ton.

ANALYSIS.

| | Per Cent. |
|---|---|
| $SiO_2$ | 41·4 |
| Cu | 11·4 |
| Pb | 9·8 |
| CaO | 0·8 |
| Fe | 3·1 |
| S | 11·3 |
| Zn | 13·2 |
| Sb | 4·2 |
| As | 3·3 |
| Ag | 1·07 |

*C. Plomosos.*—The same as black ore, *B*, but with a predominance of galena. The grade of silver in these ores is inversely proportional to the quantity of galena, and as a rule varies between 60 to 200 ounces per ton.

COMPOSITION.

| | A Per Cent. | B Per Cent. |
|---|---|---|
| $SiO_2$ | 33·2 | 33·0 |
| Pb | 30·6 | 28·1 |
| Cu | 6·8 | 8·0 |
| Zn | 11·5 | 16·3 |
| S | 12·2 | 11·1 |
| Sb | 2·1 | 1·2 |
| As | 2·6 | 0·9 |
| Ag | 0·6 | 0·88 |

*D. Milling Ores.*—Mostly ores yielding between 48 and 72 ounces per ton, and in which the blende predominates.

COMPOSITION.

| | Per Cent. |
|---|---|
| $SiO_2$ | 66·20 |
| $Al_2O_3$ | 0·30 |

| | Per Cent. |
|---|---|
| Fe | 4·00 |
| CaO | 1·80 |
| MgO | traces |
| Zn | 9·35 |
| Cu | 3·82 |
| S | 6·76 |
| Pb | 4·60 |
| Sb | 1·20 |
| As | 0·84 |
| Ag | 0·22 |

*E. Concentration Ores.*—Various ores, but of a tenor in silver of 23 ounces per ton, and which are never allowed to pass 27 ounces per ton.

As a rule the gangue is quartz or mother rock, mostly decomposed. The lode being a contact formation, is between two massifs of rhyolite and trachyte.

The sorting of the lixiviation ore requires particular care so as to avoid all kinds of decomposed rock or gangue, which is liable to interfere in the subsequent treatment of the ore by lixiviation by forming a kind of clay impeding the rapid filtration. Pure quartz, on the contrary, is rather helpful, as we will see further on.

The reduction works are about a mile from the mine, the former being situated at the foot of the hills, and on the banks of a rushing stream, which, however, is mostly dry during the dry season. The transportation of the ore is done by mules at 18½ cents (Mexican money) per cargo.

## HACIENDA DE BENEFICIO—"DIOS PADRE."

*The Mill.*—The lixiviation and concentration ores are treated directly by 20 stamps. Ten stamps are employed for the dry crushing of the lixiviation ore.

The following are the data of the 20-stamp battery:

TWENTY-STAMP BATTERY.

| | | | |
|---|---|---|---|
| Stem | 3″ x 13′ 6″ | 320 lbs. | |
| Tappet | | 147 " | |
| Head | | 220 " | |
| Shoe | | 126 " | |
| | | —— | 813 |
| Die | 75 | — 86 " | |
| Cam | | 245 " | |

| | | |
|---|---|---|
| Cam-shaft for 10 stamps | 5½″ x 14′ 7″ | 1,100 lbs. |
| Cam-shaft pulley | | 1,650 " |
| Number of revolutions of the cam-shaft per minute | | 54 |
| Number of drops per 1′ | | 105 |
| Fall in feet | | 0′·5 |
| Mortar block | 16″ x 20″ 30″ | 4,725 lbs. |
| Horse-power for 20 stamps | | 30 |

At first the pulp passed through a 30-mesh screen, but it was noticed that the lixiviation of the chloridized ore was not rapid. The filtration becoming slow, the dissolved silver probably was reduced and precipitated by prolonged contact with the sulphides of zinc and lead, or even by their sulphates, which always occur in the chloridized ore. It was therefore necessary to resort to a 16-mesh screen, and the results have been highly satisfactory.

The pulp is conveyed by a belt-elevator to a bin, from which the four roasting reverberatory furnaces are charged.

*Roasting and Chlorination Reverberatory Furnaces.*—The reverberatory furnaces are of the well-known type with four graded hearths. Dimensions: 14 x 9 feet.

The ore remains at each hearth two hours, and at the last two is continually stirred. Certain kinds of ores, especially sulphides (lately we were treating ores containing mostly blende), rich in antimony, etc., require more time, as the roasting has to be done at a very low temperature in order to avoid volatilization.

The blendiferous ores, whose analysis I have given, required three hours at each hearth, *i. e.*, twelve hours in total, the charge being 1,200 pounds.

At first, half of the necessary salt was added at the battery and the other half in the last hearth, but experience showed that it was better to add all the salt at the last hearth two hours before discharge.

The quantity of salt added varied between 4 per cent. and 8 per cent., according to the nature of the ores. At the beginning, when nothing but green ore (chrysocoll) had to be treated by lixiviation, a great deal of difficulty was encountered in the chlorination. Soon, however, we found that the sulphides existing with the green ore were in small quantities, and a great part of their sulphur was volatilized;

consequently the sulphates formed were insufficient, and required a great deal of time to be converted into that state in order to attack the salt. So we resorted to the addition of 1 per cent. of pyrites. Pyrites, as it is well known, readily loses half of its sulphur and then is rapidly converted into sulphates necessary for the production of chlorine. Even with blendiferous ores pyrites was found to help chlorination very much. With the above-mentioned green ore and the addition of the pyrites, the time of roasting and chloridizing did not exceed eight hours, and the percentage of chlorination was on an average of 97·5 per cent. Attention should be directed to the fact that in all kinds of ores, when very siliceous, we found that the chlorination was rapid and more nearly perfect.

It can be probably ascribed to the following reaction:

$$ROSiO_2 + 2NaCl = Na_2OSiO_2 + Cl_2$$

The wood which we preferred for the purpose was "torrote" and "piojo," because they produce a large flame and have a great deal of moisture, the conversion of which into steam facilitates so much the chlorination.

*Labor.*—All the men employed at these furnaces are pure Maya Indians, and it can safely be said that this kind of work is their specialty.

For four reverberatory furnaces there are employed:

| | |
|---|---|
| 2 foremen at $1.25 | $2.50 |
| 24 ore stirrers at 75 cents | 18.00 |
| 10 ore chargers, wood transporters, etc., at 75 cents | 7.50 |
| 1 salt transporter at 40 cents | .40 |
| | $28.40 |

The chloridized ore is discharged on a cooling floor in heaps, where the chlorination is still continued, as always some chlorine remains with the chloridized ore at its discharge.

*Lixiviation—Charging the Vats.*—The charging of the vats is done on contract work by four Indians. The tailings are loaded on mill dump cars and dumped into the "arroyo." The filter is repaired, and the ore which has been previously

slightly moistened and the lumps broken up is taken from the cooling floor and charged.

If the chlorination was properly accomplished, the ore at its discharge from the furnace will have a very strong odor of chlorine and change rapidly its color from dark brown to ochre, owing to the reduction of the perchloride of iron into sesquioxide; when slightly moistened it must assume a spongy appearance, and finally when pressed in the hands it must not become muddy or adhere to the hand.

These characteristics are essential to the good working of the lixiviation, and the Indians in charge of these works are well acquainted with these details.

This ore is charged up to the brim of the vat, because on lixiviating it will settle down to a foot or more below the brim.

There are nine vats.

DIMENSIONS OF THE VATS.

| | Feet. |
|---|---|
| Diameter | 20 |
| Height | 5 |
| Height of filter | 1 |

*Filter.*—The filter is the well-known one, composed of stones at the bottom, with sand and gravel on top; it does not exceed one foot in thickness.

The reduction works have nine vats of a capacity varying from 37 to 47 tons, according to the nature of the ore treated.

The lateral discharge of the lixivium is preferred, as it avoids obstructions.

All the vats are in a row and their rubber discharge pipes lead to a wooden trough, which in turn carries all the silver-bearing solution to the three precipitation vats. By its side is another trough for conveying the washings of the base metals of the ore to the cementation vats for copper.

*Leaching.*—Once the vat is charged with the ore, water is admitted from below through the same discharge outlet. The main object of this is to expel the imprisoned air and have the ore more evenly settled. When the water reaches the top of the vat, then it is admitted from above, and the rubber discharge pipe is directed to the base metal solution

trough. This solution contains mostly sulphates and chlorides of copper, zinc, iron, etc. The recovery of the copper and the little silver that might have dissolved will be the subject of another chapter.

The length of time for the removal of the greater part of the base metals through water lixiviation varies considerably, and it often requires between fifteen and twenty-four hours. When calcium polysulphide does not produce any precipitation or a very slight one, it indicates that most of the base metals have been removed, and then half of the water is allowed to run out and the calcium hyposulphite is allowed to take its place. However, before admitting this solution, the cracks and interstices formed on the surface of the settled ore, and which are liable to offer an easy outlet for the solution, are filled up by plunging around them with a shovel.

The demarkation of the substitution of the water by the hyposulphite of calcium solution has a sweetish taste, and it requires the special attention of the foreman so as to divert, in due time, the flow to the argentiferous solution trough.

The rate of filtration is a variable one, $2\frac{13}{16}$ inches being considered a good one.

DATA ON LIXIVIATION, DURING OCTOBER, NOVEMBER AND DECEMBER, 1897.

| Number of Operation. | Name of Vats. | Date of Charging the Vat. | Date of Discharging the Vat. | Initial Grade of the Ore Per Ton. | Insoluble Per Ton. | Tailing Per Ton. | |
|---|---|---|---|---|---|---|---|
| 714 . . . . . . . | *A* | Oct. 3 | Oct. 12 | 46·1 | 1·9 | 1·3 | |
| 715 . . . . . . . | *C* | " 6 | " 22 | 52·6 | 1·9 | 1·9 | |
| 716 . . . . . . . | *H* | " 8 | " 26 | 12·3 | 1·9 | 3·2 | Old Tailings. |
| 717 . . . . . . . | *B* | " 9 | " 16 | 48·7 | 2·6 | 1.9 | |
| 718 . . . . . . . | *A* | " 12 | " 23 | 40·9 | 0·6 | 4·5 | |
| 719 . . . . . . . | *I* | " 14 | " 30 | 14·3 | 2·6 | 3·2 | Old Tailings. |
| 729 . . . . . | *A* | Nov. 5 | Nov. 20 | 61·1 | 2·6 | 3·2 | |
| 730 . . . . . | *C* | " 9 | Dec. 9 | 58·5 | 1·3 | 3·9 | |
| 738 . . . . . . . | *D* | Dec. 1 | " 17 | 50·7 | 1·3 | 1·3 | |
| 740 . . . . . . . | *F* | " 7 | " 17 | 46·8 | 1·9 | 1·9 | |
| 743 . . . . . . . | *E* | " 15 | " 30 | 49·4 | 1·9 | 2·0 | |
| 747 . . . . . . . | *B* | " 23 | " 31 | 46·8 | 3·2 | 2·6 | |

A sample of the ore after charging the vat is taken, and also a sample of the tailings, and assayed.

All the argentiferous solutions by the common trough, are carried alternatively to three precipitation vats of 12 x 6 feet and 678 cubic feet capacity. There the silver is precipitated by a solution of polysulphide.

It often happens that by some cause part of the chloride of silver is reduced or otherwise acted upon, and becomes insoluble in the hyposulphite of calcium solution ; we found that by discharging the vat and leaving the ore exposed to atmospheric effects for a certain length of time, the silver becomes soluble and could be leached again with better success. This can be seen in the table of lixiviation.

(Operation No. 716, vat *H.* Operation No. 719, vat *I.*)

Mr. Nute, superintendent of the neighboring English mine, at present treats the old tailings, which his predecessors discarded, and which have been exposed for many years to atmospheric action, with a good margin of profit.

The chlorination and lixiviation cost is $17.87 per ton.

*Hyposulphite Solution.*—This solution is practically that of double hyposulphite of calcium and sodium, most of the sodium hyposulphite being converted into that of calcium by the well-known reactions of polysulphide of calcium on hyposulphite of silver.

Divers experiments carried on for a considerable length of time proved that the best strength was between 0·55 per cent. and 0·60 per cent., as a stronger solution dissolved the remaining base metals of the ore, which at the precipitation vats rendered the precipitate a serious difficulty, to say nothing of the lowering of the grade of the silver sulphide.

A daily determination of the strength of the solution is a matter of a few minutes, by a standardized solution of 5·121 grams of iodine into 7 grams of potassium iodide, the reaction being the following:

$$2Na_2S_2O_3 + 2I = 2NaI + Na_2S_4O_6.$$

*Precipitation of Silver.*—The precipitation of silver is done with a calcium polysulphite solution. Care must be taken to avoid an excess of the said solution, as it will cause pre-

cipitation of the silver in the leaching vats when the hyposulphite solution is decanted and used over again.

In practice they add calcium polysulphide until a few drops of it in a glass of the argentiferous solution produces a milky appearance. It is always preferable to have too little than too much calcium polysulphide in the hyposulphite solution. After stirring it with a wooden stirrer the precipitate is left to settle and the solution decanted by means of a rubber pipe into storage tanks, whence it is pumped by a centrifugal pump to a tank 5 feet above level of the leaching vats.

Polysulphide of calcium solution. $Ca\ S_5$.

| | Diameter. | Height. |
|---|---|---|
| A | 8′ | 6½′ |
| B | 6′ | 6′ |
| C | 10′ | 3′ |

The vat *A* is filled up to 1 foot with water and boiled with steam. Then quicklime is added and the boiling is continued for a while. Finally, sulphur is added and the boiling continued for five or six hours. The stirring is done mechanically. The proportions are as follows:

| | |
|---|---|
| Sulphur | 70 |
| Lime | 100 |

The solution obtained after settlement is decanted into a storage tank. The residue is treated again with water and steam and then a smaller quantity of lime and sulphur are added in the proportion of $CaO = 79$. $S = 56$.

This second residue is discharged on the sand filter of vat *B*. When dry it is put aside and exposed to the atmospheric action. A long exposure of this residue gave us 6·2 per cent. of calcium hyposulphite. Each operation gave us 6,213 liters of calcium polysulphide at a cost of 69 cents.

Let me mention that sulphur in Aduana costs 7·4 cents per pound.

[*To be concluded.*]

# CHEMICAL SECTION.

*Stated Meeting, February 15, 1898.*

## THE CHEMICAL COMPOSITION AND TECHNICAL ANALYSIS OF WATER GAS.

BY EDWARD H. EARNSHAW,

Chemist to the United Gas Improvement Company, Philadelphia, Member of the Institute.

(*Concluded from p. 176.*)

### SUPPLEMENTARY NOTE.

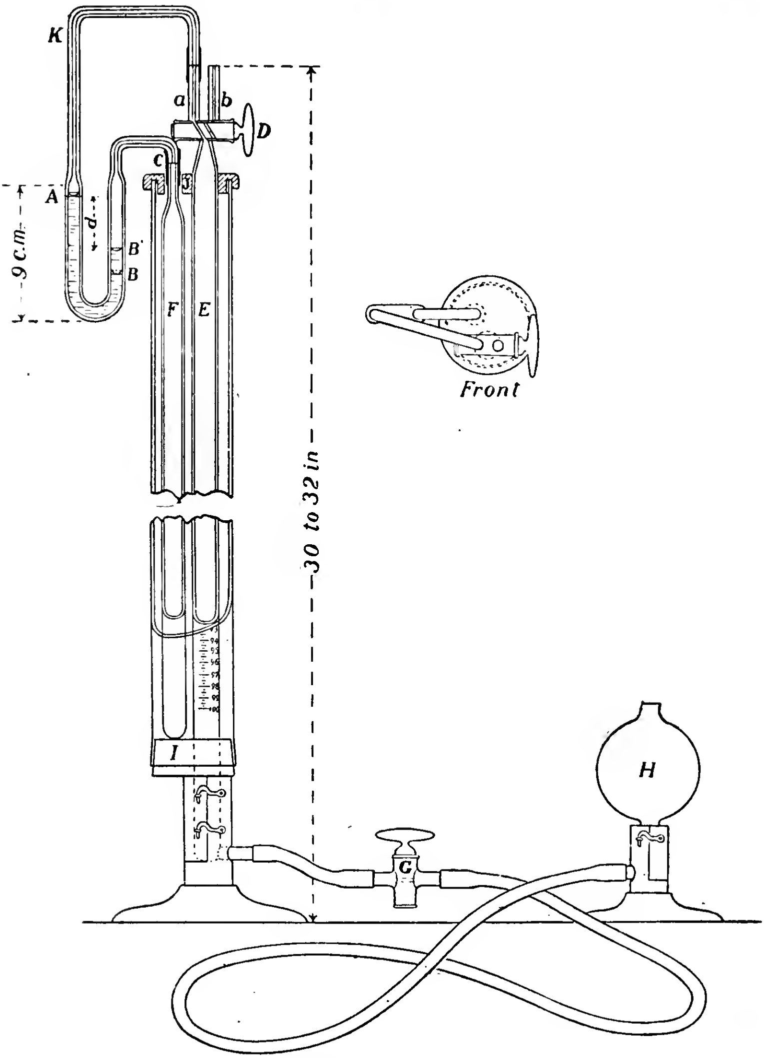
The satisfactory performance of a gas analysis depends in great measure on the accurate measurement of the various gas volumes—a result difficult to attain in the more usual forms of apparatus.

A most satisfactory instrument is found, however, in the burette with correction for temperature and pressure described on p. 28 of Hempel's "Gas Analysis." In this apparatus the gas volume is not measured at atmospheric pressure, but by means of a manometer it is brought to the pressure of a constant volume of air enclosed in a Pettersson correction tube. The enclosed volume of air is always at the same temperature as the gas volume, since the burette and the correction tube both stand in the same wide tube filled with water.

Experience has shown the advisability of departing in the following particulars from the method of operation described by Hempel:

A mark is placed on the manometer at *A*, and another mark is placed on the other limb of the manometer at *B*, about an inch above the bottom. The mark at *A* should be located so that the size of the space from *A*, to include the stopcock *D*, shall be exactly 1 cubic centimeter. This may readily be done thus: Withdraw the manometer tube from the connection at *C*, then, by raising the level bulb *H*,

fill the measuring tube and manometer completely full of water. Now draw some air into the burette and note the volume at atmospheric pressure, after allowing sufficient time for the water to run down. Then turn the stopcock *D*




so that the burette communicates with the manometer, and, by raising the level bulb, pass a little air over into the manometer, and at the same time force a little of the water

out of the open end of the tube at *C*. By a little manipulation the volume of the air in the burette may thus be diminished by exactly 1 cubic centimeter, while at the same time the liquid in the manometer stands at the same height in both sides.

In the ordinary use of the burette it is very inconvenient to measure the gas volume with the liquid in the manometer at the same level in both sides, because there is great liability that some of the water will accidentally be forced over into the correction tube, and also because a free space is needed to enable the water in the manometer to be moved up and down, and thus clear the connecting tube of the annoying drops of water which persistently remain in it. It is therefore better to make the measurement as follows: Draw the water in the manometer over into the burette until the liquid in one side stands exactly at the mark *B*, and the other side is completely filled to the stopcock *D*. When now the gas volume in the burette is to be measured, turn the stopcock *D* so that the burette communicates with the manometer, and, by raising or lowering the level bulb *H*, bring the water in one side of the manometer exactly to the mark *A*; the liquid in the other side of the manometer will then stand at *B'*. Close the stopcock *G*, and note the size of the gas volume, which will be the reading of the scale plus 1 cubic centimeter.

By this method the pressure in the burette, instead of being equal to the pressure in the correction tube *F*, will differ from it by a constant amount equal to the difference *d* between the levels of the liquid in the two arms of the manometer.

It will usually happen in drawing the gas in the manometer back into the burette that the liquid in the manometer will be drawn slightly below the mark *B*. This is of no consequence, as, when the gas has been passed from the burette to the absorption pipette, the stopcock *D* may be turned, and a little water passed from the burette into the manometer. By this method of operation it is assured that the measurements of the gas during an analysis will be made under absolutely uniform conditions.

Before beginning an analysis, it is advisable to bring the water in the manometer to the mark *A*, close the stopcock *D*, and draw the manometer tube out of the connection at *C*. This will establish atmospheric pressure in the burette and correction tube.

Some points in the construction of the burette are worthy of note. The measuring tube *F* should have an internal diameter of about 15 millimeters; the instrument will then have a total height of 30 to 32 inches. The correction tube may be about the same size, or slightly smaller, and must be just long enough to rest on the rubber stopper *I*, at the bottom and project about ½ inch above the wooden cap *J*. This wooden cap serves to hold the tubes in their proper position in the water jacket, and also prevents the manometer from sagging down. The water jacket tube must be cut of such length that the rubber stopper *I* rests firmly on the burette base, while the top of the tube ends about 1 inch below the stopcock *D*. In *Fig. 1* the correction tube and burette are, for convenience' sake, shown side by side. As a matter of fact, they are arranged as shown in *Fig. 2*. The holes are carefully bored in wooden cap and rubber stopper so as to bring the measuring tube parallel to and near the front of the water jacket. The correction tube is placed behind and to one side of the measuring tube, and the connecting tube to manometer is bent at an angle, as shown.

The U-shaped part of the manometer is about 9 centimeters long and 8 millimeters internal diameter. The connecting tube *K* is 6 millimeters outside diameter and 2 millimeters bore. The capillary tubes *a* and *b* are 1½ inches long and 1 millimeter bore.

The stopcock *G* should be large, and it will be found necessary to secure it in a small wooden block fastened to the table in a convenient position. The iron foot of the burette should also be screwed to the table, as the apparatus is quite top-heavy. It is convenient to use two burettes for the analysis. One is graduated from the stopcock *D* to 100 cubic centimeters in tenths of 1 cubic centimeter, and is used for the direct absorptions; the other is graduated from 60 cubic centimeters to 100 cubic centimeters in twentieths,

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HENRY TRIMBLE.
1853–1898.

the upper part of the measuring tube being enlarged into a cylindrical bulb and not graduated. This latter is used exclusively for the explosions and combustions, where great accuracy is essential.

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*Stated Meeting, September 20, 1898.*

## IN MEMORIAM.

### HENRY TRIMBLE.

The Franklin Institute has lost another of its members and active supporters, and chemical science one of its trained workers and devoted followers in the death of Prof. Henry Trimble, which took place at St. Davids, near this city, on the 24th of August, 1898.

Those of our number, who had the pleasure of an intimate acquaintance with him, and knew that under a quiet and somewhat retiring manner lay a warm heart and devoted friendships, feel in addition a sense of personal loss that cannot easily be weighed or expressed by the use of ordinary conventional phrases.

Henry Trimble was born near Chester, Pa., on May 22, 1853, the son of Stephen M. Trimble, a member of the Society of Friends. He was brought up on a farm, going to school in winter and working during the summer. His earlier education was obtained at the well-known Westtown School in Chester County, and at the age of nineteen he was apprenticed to learn the drug and apothecary business.

Two years later, in 1874, he entered the Philadelphia College of Pharmacy, the institution in which most of his subsequent active career was to be cast, and was graduated therefrom in 1876. Desiring to supplement his course here by a fuller training, he then entered the University of Pennsylvania as a special student in chemistry, to which branch of scientific study he felt already strongly drawn. He continued here during two years, working in the analytical laboratory under the late Dr. F. A. Genth, and for the last year of his time there acting as lecture assistant to Professor Sadtler,

who then held the chair of General and Organic Chemistry in that institution.

When in the fall of 1878, Professor Sadtler was called to the College of Pharmacy to take the lectures of the late Dr. Robert Bridges (then the Professor of Chemistry there), he took Henry Trimble as his lecture assistant there also. In this same year, 1878, he established himself in the retail drug business, with his friend and classmate, C. W. Warrington, the two taking the business of their preceptor, S. Mason McCollin, M.D., at Fifth and Callowhill Streets, in this city.

Meanwhile the chemical laboratory of the College of Pharmacy having also come under the care of Professor Sadtler, by reason of the resignation of Dr. Fred. B. Power, Henry Trimble was given the active supervision of this, and in 1883, having retired from active connection with the drug business, he was given the full rank and title of Professor of Analytical Chemistry in the institution.

From this time on, all his energies and efforts were given to this work, and the literature of pharmacy and chemistry will bear witness that, all too short as was his term of scientific activity, he left his mark upon their pages.

As director of the laboratory he had to plan and supervise the work of advanced students, and each year many original investigations in analytical chemistry and proximate plant analysis were carried out under his guidance.

The list of published articles which appeared in the *American Journal of Pharmacy*, under his name during the years 1875–1898 was fifty-four in number.

Already, in 1890, he had begun to make a special study of the class of vegetable principles known as tannins, being incited thereto by some investigations which he had made into the methods of dyewood extract manufacture. So in 1892 he published, in a small octavo, the first volume of a work with the following title: "The Tannins; a monograph on the history, preparation, properties, methods of estimation and uses of the vegetable astringents." In 1894 he followed this by a second volume, and, at the time of his

death had a large amount of unpublished notes which were meant to be used in a continuation of this unique publication. It is strictly correct to say unique, because the work at once took rank in this country and abroad as the authoritative work on the subject, and Professor Trimble had for years carried on an extensive correspondence with botanists and chemists in all parts of the world upon what was known as his specialty.

In this connection it should not be overlooked that Professor Trimble was an accomplished botanist, having taken special advanced instruction in this subject while a student at the University, and afterwards from Professors Rothrock and W. P. Wilson.

This familiar acquaintance with the two domains of chemistry and botany made it an easy matter, therefore, for him to co-operate with his colleague, the late Prof. E. S. Bastin, in a series of joint articles on "Some North American Coniferæ," which appeared in the *American Journal of Pharmacy*, and were reprinted in separate form in a pamphlet of some 124 pages.

He also became a contributor to *Garden and Forest*, published under the editorship of Professor Sargent, of Harvard University, and during the years 1894–98 furnished seven articles for this periodical. An article on the Coniferæ was also contributed by him to Sargent's monumental work, "Silva of North America," appearing in Volume XI.

In 1885 he published a small "Handbook of Analytical Chemistry," for the use of his laboratory students. It ran through several editions and was then merged into the "Text Book of Pharmaceutical and Medical Chemistry," first published by Professor Trimble and Professor Sadtler jointly in 1895, and which has just appeared in a second revised edition.

As a member of the Franklin Institute, Professor Trimble was called upon several times to lecture in the regular winter lecture course, and only a year or so ago gave us here a most instructive lecture upon the recent researches into the composition of "Natural Resins." These lectures of his will be found printed in full in our *Journal*.

Professor Trimble has repeatedly received public honors which came as a recognition of his attainments. He had the honorary degree of A.M. conferred upon him by Haverford College in 1896.

In 1895, he was selected as one of the Judges of Award for the Atlanta Exposition in the Forestry Section.

In 1897, he was elected a member of the American Philosophical Society, and because of his knowledge of the branch of sylviculture was made a member of the Standing Committee on the Michaux Legacy.

In 1894, he was elected editor of the *American Journal of Pharmacy*, to succeed the late John M. Maisch, and at once threw himself with additional energy into this new sphere of work.

This editorial labor, with the necessary correspondence and work of proof-reading for each monthly issue, which he would not delegate because of his feeling of personal responsibility, proved too much for his strength, already tasked quite sufficiently.

In the spring of 1897, he broke down partially and was forced to give up some of his work. But improving somewhat, he took up his joint college and editorial work again, and continued until in May, 1898, he was forced to place the editorship of the *Journal* in other hands and seek entire rest.

But the seeds of fatal disease were already sown, and in August came the end of his life's activity.

He has left us a name and a memory. A name for workers in his chosen science, and especially for young men to emulate, as he showed in his career what a plain farmer's son could make of himself by effort. A memory for those who were privileged to know him, of a true-hearted and faithful friend, who was always the same, and whose word could always be relied upon implicitly.

A list of published papers and other works of Professor Trimble will be found appended to this memoir.

SAML. P. SADTLER,
CHAS. BULLOCK,
T. CHALKLEY PALMER.

## PUBLISHED PAPERS OF HENRY TRIMBLE.

### I. *American Journal of Pharmacy.*

1875. Assay of quinine pills.
1876. Benzoic acid as an antiseptic.
1877. Concentrated nitric acid.
  Estimation of quinine.
1878. Analysis of dialysed iron.
1881. Preparation of formic ether.
1883. Milk analysis.
1884. Menthol.
1885. Glycerin vapors.
  Oils of peppermint and spearmint.
  Polygonum hydropiper (jointly with H. J. Schuhard).
  Burdock Fruit (jointly with F. D. McFarland).
1886. Analysis of Yerba del Indio (jointly with S. S. Jones).
  Analysis of Phlox carolina.
1887. Amyl acetate.
  Laboratory notes.
1888. Sheperdia argentea.
  Bitter principle of burdock fruit.
  Catechu and gambier.
  Precipitated ferrous sulphate.
  Solid hydrocarbons in plants (jointly with Helen C. De S. Abbott).
1889. Canaigre.
  Some Indian plant foods.
  Fabriana imbricata (jointly with H. J. M. Schroeter).
  Oil of camphor (jointly with H. J. M. Schroeter).
  Oils of wintergreen and birch (jointly with H. J. M. Schroeter).
  Old sample of camphor oil (jointly with H. J. M. Schroeter).
1890. Eupatorium purpureum.
  California soap plant.
  Peucedanum Canbyi.
  Some American galls.
  Oils of wintergreen and birch (jointly with H. J. M. Schroeter).
1891. Carum Gairdneri.
  Geranium maculatum (jointly with J. C. Peacock).
1892. Examination of some official preparations.
  Purshia tridentata.
1893. Proximate principle from Phytolacca decandra.
  Preparation of oak tannins, acetone a solvent (jointly with J. C. Peacock).
  Canaigre tannin (jointly with J. C. Peacock).
1894. Four oak barks from India.
  Cultivation of ginseng.
1895. Oils of wintergreen and birch.
  Report on tannin from dragon's blood.
1896. Recent literature on soja bean.
  Tannin of some acorns.

1897. Occurrence of strontia in plants.
Pomegranate rind.
Tannin of Castanopsia.
Tannin of Ceriops candolleana.
The soy bean.
The willow bark.
North American coniferæ (jointly with Prof. E. S. Bastin).
1898. An exudation from Larix occidentalis.

II. *In Garden and Forest.*

1894. Pin oak (Quercus palustris).
1895. On the tanning properties of the bark of three North American trees.
1896. Salt and sugar in Washingtonia filamentosa.
Tannin value of North American trees.
Tannins of the palmetto.
1897. Source of abietene.

III. *In Franklin Institute Journal.*

1887. Tannin, its present and future sources.
1892. Chestnut bark tannin.
1897. Recent advances in the study of the resins.

PROFESSOR TRIMBLE'S BOOKS.

I. *Hand-book of Analytical Chemistry, 8vo. P. Blakiston, Son & Co.*

1st edition, 1885.
2d edition, 1886.
3d edition, 1889.
4th edition, 1892.

II. *The Tannins—a Monograph. J. B. Lippincott Co.*

Vol. I, 1892.
Vol. II, 1894.

III. *Text-book of Pharmaceutical and Medical Chemistry (jointly with S. P. Sadtler).*

1st edition, 1895. J. B. Lippincott Co.
2d edition in two volumes, 1898. J. B. Lippincott Co.

# NOTES AND COMMENTS.

## THE LATEST SCHEME FOR THE PASSAGE OF THE ENGLISH CHANNEL.

Since the collapse of the long-mooted project for a tunnel under the English Channel, connecting England and France, but little has been said concerning the subject of facilitating the channel passage. Interest in the subject has at length been revived by the publication of a scheme which is referred to by *Industries and Iron* as having lately been brought to the attention of the authorities in London and Paris. The journal in question gives the following outline of the present project:

The idea is to secure a passage for trains without involving the cost of a bridge or the danger of a tunnel, and may be described as an exemplification of the electric railroad on submarine rails, carried out on a small scale from Brighton to Rottingdean, England.

It is proposed to lay rails on a track about fifty feet below low-water level, and the train would be conveyed from Dover to Calais, or *vice versa*, on a tower-like structure running on these rails in the bed of the straits. The train platform would be about 500 feet long and 50 feet wide, carried on five steel columns on each side, and these would be braced to and supported on a submerged platform on the series of rails, which would be 100 feet wide. Steam engines and dynamos on the train platform would provide the power for rotating the train wheels on the lower platform. The cost of the undertaking is estimated at fourteen million pounds sterling (about $70,000,000), and five years is the limit of time in which it could be completed. W.

## ALUMINUM FOR ELECTRIC CONDUCTORS.

Mr. Alfred E. Hunt, who is prominently identified with the development of the aluminum industry, has lately presented, in the columns of the *Electrical World*, a strong argument in favor of the substitution of aluminum in place of copper for electric conductors, for telegraph, telephone and railway services.

Mr. Hunt points out that while the electric conductivity of aluminum is 63 per cent. of that of copper, the weight of the latter metal is 3·33 times that of an equal volume of aluminum. From this it appears that even by increasing the cross-section of an aluminum conductor sufficiently to give it equal conducting with copper, the weight of the larger aluminum conductor would still be only 48 per cent. of that of the copper conductor.

As to the matter of cost, Mr. Hunt says:

"To obtain, therefore, a conductor of aluminum at the same cost of metal per mile, the cost per pound of the aluminum may be 2·1 times greater than that of copper. Assuming the cost of the copper at 14 cents per pound, it is evident that aluminum at 29 cents per pound is slightly cheaper than copper."

Furthermore, the important matter of tensile strength in this comparison

determines itself in favor of aluminum. Aluminum wire can be supplied at about the same tensile strength per unit of area as that of annealed copper—32,000 pounds per square inch; but as the aluminum conductor will have a larger area to make up for its deficient conductivity, it will be the stronger.

With reference to the use of alloys of aluminum for this purpose, Mr. Hunt points out that while a number of such alloys can be made which are much stronger than the pure metal, they appear as a class to reduce the electric conductivity. One of these alloys which he refers to, however, appears to be well adapted for the production of electric conductors. It has a tensile strength of 65,000 pounds per square inch, and an electric conductivity of 50.

The one difficulty that is encountered in the manipulation of aluminum is that of soldering or brazing it, and this would be encountered here also. It is suggested that mechanical joints might be tried with more prospects of success. On the other hand, the difficulty would probably be entirely obviated by the adoption of the method of electric welding by which no foreign metals would be brought into contact with the aluminum.

The experiment of using aluminum for this purpose has been made with apparently satisfactory results in this country and in Germany. It resists corrosion very well. W.

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## A SLIDING OVERHEAD TROLLEY.

The use of the under-running roller trolley has become so universal for electric cars, that its superiority over other forms has been taken for granted. It now appears that the Germans have made some very satisfactory trials of a sliding contact trolley, which show that the alleged superiority of the roller is more apparent than real.

The following facts in relation to this point are given in *Engineering Magazine*, and relate to the use of a double or forked trolley arm which carries a light, slightly-bowed horizontal bar, which is pressed upward against the conducting wire in the manner of a trolley wheel, the contact being entirely a sliding one. The contact bar is formed of an aluminum channel bar, with a central bar of white metal, the spaces between being filled with a lubricating grease. This is the plan in use on the trolley system of Dresden.

The bar thus constructed lasts from six to eight weeks, corresponding to 8,000 car kilometers (6,400 car miles), and the general results are satisfactory. Also, contrary to what might be supposed, the wear on the line wire is less than with the roller trolley; for, with the roller, the side wear on the wire is very great, especially upon curves, which, with the sliding bar, after a slight flat bearing has been worn on the conductor, further wear seems to be trifling. On the Dresden lines the conductors are of copper. At Basle the line wire is of aluminum, and therefore of greater diameter. In this case the contact area is increased and the wear is diminished. The sliding trolley bar in this case lasts two or three times longer.

It is reported that, in addition to the two cities above named, the sliding trolley bar has been given practical service in Berlin, Mulhausen, Hanover, Barmen and other German cities, and that it has been found preferable to the roller trolley for the reasons above named. W.

## CRYPTON: A NEW ELEMENT IN AIR.

London advices of recent date refer to the probable discovery by Professor Ramsey (who, jointly with Lord Rayleigh, discovered argon) and Mr. Morris Travers, of another hitherto unknown gas existing in the atmosphere. A brief account of the work of these investigators was lately communicated to the French Academy of Sciences through M. Berthelot, the principal facts of which are as follows: Messrs. Ramsey and Travers received from Dr. Hampson 750 cubic centimeters of liquid air, which was partially evaporated. The residual liquid furnished a gas in which the supposed new element was detected. The method of procedure consisted in absorbing and removing the oxygen and nitrogen by well-known methods, after which there remained 26 cubic centimeters of gas, which, when examined with the aid of the spectroscope, exhibited spectrum lines unlike those of any hitherto known gas.

The facts as reported seem to indicate, according to the authors, that the atmosphere contains a hitherto unknown gas heavier than argon, with a characteristic spectrum, and less volatile than either nitrogen, oxygen or argon. Professor Ramsey is disposed to class it with the recently-discovered element helium. Larger quantities of the gas are being prepared for the more thorough study of its properties.

Professor Ramsey names the new substance "crypton." W.

## REMEDY FOR DIFFICULTIES IN BURNING ACETYLENE GAS.

Prof. Vivian B. Lewes, an eminent English chemist, who has done much valuable work in extending our knowledge of the properties and applications of acetylene gas, has lately contributed an interesting paper on this general subject to the (English) Society of Chemical Industry. In this communication he deals at some length with the difficulty which exists in finding a suitable burner in which to consume the gas, and throws much light upon the cause of the difficulty. All who have had experience with acetylene are familiar with the fact that there is a persistent disposition to the deposition of soot in the burner tip, which, in the course of a short time causes the clogging of the tip, followed by the distortion of the flame and pronounced smoking. Numerous efforts have been made to do away with this objectionable feature, but thus far with only partial success. Among the remedies that have been proved most satisfactory is the Naphey burner and its various imitations, but these have proved to be by no means infallible, and the difficulty appears to be as far from solution as ever.

Professor Lewes has studied the character of this soot deposit and offers some explanations of its nature and cause, which point to the proper remedial measures.

It has been generally supposed that the soot deposit noticed in the burner slit or tip consuming acetylene was due to the dissociation of the gas from overheating at the nipple, the decomposition resulting in the separation of carbon. Professor Lewes believes this is not the true explanation of the origin of this deposit.

On breaking open the steatite tip of such a burner, he found a carbona-

ceous deposit extending for a considerable distance into the body of the steatite, and this he holds to be evidence of the fact that the deposit has been caused by the deposition of a liquid hydrocarbon, which has soaked into the steatite and been carbonized there. He calls attention to the fact that the same trouble is experienced to some extent with carburetted water gas, when, owing to insufficient temperature in the cracking and superheating chambers, the carburetted gas contains vapors instead of permanent gaseous products. His observations lead him to the belief that the trouble in the case of acetylene arises from a similar cause, namely, the presence in the gas of condensible hydrocarbons, the origin of which he explains as follows:

"When acetylene has been made in a generator at an undue temperature, it carries with it benzene vapor, which, as it commences to condense, assumes a vesicular form (like smoke or tar vapor), and on coming to the extremely minute holes which form the apertures of the burner, the mechanical scrubbing which it encounters causes the breaking up of the vesicles and the deposition of the benzene and other hydrocarbons held in suspension in the gas, which soak into the steatite and carbonize. The presence of finely divided carbon has a great effect in determining the decomposition of acetylene itself, so that a rapid growth of carbon takes place at the burner, and no ordinary cleaning from the exterior will ever make the nipple fit for constant use again."

The remedy for the trouble, Professor Lewes believes, must be sought for in the improvement of the automatic acetylene generators in service, with the object in view of avoiding undue heating in the process of generating the gas. If proper attention is paid to this point, not only will the sooting of the burner be largely avoided, but there will also be obtained an appreciable increase in the yield of the gas from the carbide. His conclusions are expressed in the following terms: "It will be found with experience that the prevention of smoking in a burner will be effected quite as much by attention to the temperature in the generator as to the burner itself, and where a generator is in use which gives overheating, a well-arranged scrubbing apparatus that would get rid of the benzene in the gas, would be found a distinct advantage in stopping burner troubles."

The practical hints herein given by Professor Lewes should prove of the utmost value to those who are engaged in the manufacture of acetylene machines, and the users of the gas. W.

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## THE UNFITNESS OF CAST-IRON COLUMNS IN BUILDING CONSTRUCTION.

Prof. William H. Burr has given, in the School of Mines Quarterly, a timely warning against the continued use of columns of cast-iron in building construction which it would be well for architects to bear seriously in mind. Professor Burr shows that the rules followed by engineers in respect of the loading per square inch of cast-iron columns in buildings are based on experiments made sixty years ago, on small cross sections (solid and hollow), not over four inches in diameter, and with lengths not exceeding ten feet.

Commenting on this fact Professor Burr very properly makes the criticism that columns of such diameters—particularly if cast for experimental purposes —will obviously be far freer from the internal defects so common to full-sized cast-iron members than the columns used in structures, and he adds that it has long been accepted as one of the cardinal principles in civil engineering that the untimate resistances of full-sized members of all descriptions can only be determined with sufficient accuracy for the best practice by testing such full-sized members to failure.

The fact that civil engineers have long since excluded cast-iron columns from bridge structures affords evidence of the unfitness of cast-iron for such service, and renders it the more important in view of the continued use of this material in buildings, that engineers should have at command the results of destructive tests of full-sized members of cast-iron from which the working loads that such columns may safely bear may be determined.

Such needed tests, Professor Burr points out, were begun in 1888-1889, at the United States Arsenal, at Watertown, Mass., the large Emery testing machine being used for the purpose. These were followed in 1896–1897 by a series of tests of similar character made at Phœnixville, Pa., under the auspices of the Department of Buildings of New York City.

The tabulated results of these tests show considerable variations in the ultimate resistances even for the same ratio of length over diameter. Thus, in Nos. 1 to 6, in which the ratio of length was 12·7, the ultimate resistances vary from 24,000 pounds per square inch to over 40,000 pounds per square inch, with no fraction at the latter value. Again, No. 25 (ratio less than 20), exhibited an ultimate resistance of nearly 47,000 pounds per square inch, which is excessively high.

These erratic results, Professor Burr adds, are not to be regarded as surprising when the ordinary character of cast-iron is considered. Failures of columns, he continues, are frequently found recorded with remarks as the following: "Foundry dirt or honey-comb," "bad spots," "cinder pockets and blow holes near middle of column," "flaws and foundry dirt at point of break." Which means that it is a common experience to find that defects, such as flaws, or blow holes, or thin metal determined the place of failure.

Professor Burr then submits to a critical examination the present formula in use for the proportioning of cast-iron columns, and concludes that for hollow round columns of this material it is grossly wrong, both as to the law of variation of ratio of length over diameter and as to the value of ultimate resistances. He illustrates his argument with the aid of a graphical diagram which exhibits that present practice is based upon an utterly erroneous and dangerous formula.

Of much interest is the concluding portion of this paper, in which Professor Burr compares the ultimate resistances per square inch of mild-steel columns—as determined by actual tests with the ultimate resistances of cast-iron columns. From this comparison it appears that the steel column is from 40 to 50 per cent. stronger than the cast-iron columns—the same ratio of length over diameter being taken in each comparison. He concludes not taking into consideration the erratic and unreliable character of cast-iron, these tests

show that the safe working resistance per square inch for mild-steel columns may reasonably be taken as twice as great as for cast-iron.

He concludes his strong argument in favor of the exclusion of the cast-iron columns from building construction, and the substitution therefor of steel columns, with the following recapitulation :

"The series of tests of cast-iron columns (herein referred to) largely destroys confidence in the cast-iron column designs of the past. The results of the tests constitute a revelation of a not very assuring character in reference to cast-iron columns now standing, and which may be loaded approximately up to specification amounts. They further show that, if cast-iron columns are designed with anything like a reasonable and real margin of safety, the amount of metal required dissipates any supposed economy over columns of mild steel. As a matter of fact, these results conclusively affirm what civil engineers have long known, that the use of cast-iron columns cannot be justified on any reasonable ground whatever." W.

# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, September 21, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, September 21, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 92 members and visitors.

Additions to membership since last report, 4.

Mr. Robert D. Kinney was elected a member of the Committee on Science and the Arts, for the unexpired term of Mr. P. A. Winand, resigned.

Mr. Paul J. Schlicht, of New York, presented a paper on "A New Process of Combustion." Mr. Schlicht's process is an automatic down-draught system, adapted to furnaces of all kinds ; not only to furnaces of steam boilers, but also to house heaters. The communication was discussed by Messrs. Outerbridge, Scott, LeVan and the author. The paper is reserved for publication, and the subject was referred for investigation and report to the Committee on Science and the Arts.

Mr. R. J. Fisher, of New York, exhibited and described the Fisher Book-Typewriter. The machine is designed for printing directly in record books, and may be readily converted into an ordinary writing machine for correspondence. (Referred to the Committee on Science and the Arts.)

Mr. Ernest M. White, of Philadelphia, exhibited and described certain improvements in chimneys and globes for incandescent gas lights. They are designed, respectively, to permit the use of torn and otherwise imperfect

mantles of the Welsbach type, which would otherwise have to be discarded, and to protect the light from extinguishment by wind or drafts.

The Secretary exhibited and described the Mason Safety-Tread for stairways, sidewalk lights, etc. An abstract of the monthly report appears in the *Journal.*

Adjourned. WM. H. WAHL, *Secretary.*

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## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, September 7, 1898.*]

MR. SAMUEL SARTAIN, in the chair.

Reports on the following subjects were considered:

(No. 2003.) *Automatic Air-Brake Mechanism.*—G. F. Jeffries, Reading, Pa.

(No. 2009.) *Chimney for Incandescent Gas Lights.*—Ernest M. White, Philadelphia. [Referred back to Sub-committee for revision.]

The following cases were terminated.

(No. 1977.) *Trolley-Car Fender.*—Henry Lotzgesell, Philadelphia.

ABSTRACT.—The device is made of three metal frames, of about the width of the car tracks, with rope netting stretched across them, and being hinged together and so mounted and secured to the front of the car that normally two of the frames form an inclined plane reaching from about the height of the car floor to a point very near the ground. The third frame stands upright at the back of the other two and near the car dasher.

The whole structure may be adjusted at any desired angle by chains and side bars, and the front edge of the lower frame is furnished with a buffer of soft material for the protection of a person struck by it.

The hinged sections are so connected that they will fold up partially when a heavy body falls upon them, thus furnishing a crib within which the person is held.

Provision is also made by which the whole structure can be folded up close to the car dasher, and for transferring the fender from one end of the car to the other. The device can be cheaply built from materials purchasable on the market.

The report speaks of the device as "a good one," but finds that almost all of the details thereof have been anticipated by other patentees. A list of these anticipating patents is appended to the report.

The invention is covered by letters-patent of United States, No. 570,099, October 27, 1896, to Henry Lobzgesell. [*Sub-Committee.*—H. R. Heyl, Chairman; T. Carpenter Smith.]

(No. 1963.) *Ordinance for the Regulation of Smoke Nuisance.*

The Sub-Committee to which the draft of ordinance previously submitted was referred for further consideration, presented an amended draft. This was discussed, amended in unessential features, and adopted. Ordered to be transmitted to the Board of Managers. [*Sub-Committee.*—A. E. Outerbridge, Jr., Chairman; John Birkinbine, Chas. A. Hexamer, Dr. Coleman Sellers.]

(No. 1999.) *Protest* of Thos. Armat, Washington, D. C., against the award to C. Francis Jenkins for his phantoscope.

The Sub-Committee presented a report reviewing the statements and claims of Mr. Armat in detail. The Committee concludes that the protestant had failed to establish his objections. Report adopted and protest dismissed. [*Sub-Committee.*—H. R. Heyl, Chairman; John Carbutt.]

(No. 2010.) *Protest* of John S. Cook, Atlanta, Ga., against report on his invention of an improved journal-box.

The Sub-Committee, after examination of Mr. Cook's objections, reported in favor of sustaining the report as originally made and adopted. [*Sub-Committee.*—J. Logan Fitts, Chairman; H. F. Colvin.] W.

## SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Wednesday, September 14th. Mr. A. E. Outerbridge, Jr., President, in the chair.

The meeting was devoted to an informal discussion of the work of the Section during the present season. The preliminary program for the year was presented and read.

CHEMICAL SECTION.—*Stated Meeting* held Tuesday, September 20th, Dr. Lee K. Frankel, President, in the chair.

Dr. Frankel made some remarks appropriate to the inauguration of the season's work, and presented and commented on the preliminary program of papers prepared by the Committee on Papers.

Mr. Hudson Maxim, of New York, presented a paper, entitled "High Explosives and Smokeless Powders, and their applications in Warfare." The speaker gave a historical introduction to his theme, and proceeded to advocate the use of projectiles containing heavy charges of high explosives in great guns, which, he claimed, could be done with safety, and with destructive effects enormously greater than with the small explosive charges of black powder at present issued with heavy projectiles. [Referred for publication.] W.

# JOURNAL

OF THE

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OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLVI, No. 5. 73D YEAR. NOVEMBER, 1898



# The Franklin Institute.

## THE ENDOWMENT FUND.

The accompanying circular-letter, issued by the Committee on Endowment, with the approval of the Board of Managers, and sent to all members, fully explains the aim and expectations of the Committee.

It is the earnest wish and hope of the Committee that all the members should participate in this movement to relieve the pressing financial needs of the Institute. Accordingly, the Committee trusts that

members will not hesitate to subscribe at once for whatever amount they may feel disposed—no matter how small.

The growth of the various departments of the Institute by natural accretion, and the pressing demands for the extension of its work in various directions, have, during the past decade, increased the costs for maintenance and administration, and have been the cause of a deficit in nearly every year, notwithstanding the most careful husbanding of its resources.

It is of the utmost importance for the future prosperity and progress of the Institute, that a substantial addition to its annual revenues be acquired, not only to provide income sufficient to carry on its present work, but also to enable it to extend this in other directions; and it is the earnest desire and hope of the Board that the membership of the Institute generally will make a prompt and generous response to the appeal of the Committee on Endowment. W.

## AN APPEAL FOR THE ENDOWMENT FUND.

PHILADELPHIA, October 1, 1898.

The Franklin Institute of the State of Pennsylvania, founded in 1824, is known to every citizen of Philadelphia interested in technical and scientific work, and it is proposed, in the near future, to still further expand the work of the Institute.

The Managers of the Institute are making an earnest effort to raise an endowment fund, and a Committee has been formed to bring before the members and friends of this world-famous society, its needs and requirements, to enable it to preserve the reputation it has brought the City of Philadelphia, and to continue the assistance given to its industries of every nature, as a fitting commemoration of its 75th anniversary, which will occur February 5, 1899.

The Managers are compelled to ask this aid by reason of the increase in necessary expenses, which now exceed the net revenue. The present endowment is small, and although the membership of nearly 2,000 contributes an annual addition to the income, this is not sufficient to carry on the work. The membership is composed largely of artisans, and the dues ($8.00 per year) are properly low, so that the benefits of the Institute may reach as many as possible.

One of the most complete scientific libraries in the world is now housed in a building which is not fire-proof (although a portion of it has been recently made as nearly so as possible under existing conditions), and the funds available are insufficient to properly maintain and increase it.

A fund of $350,000 is deemed requisite to adequately provide the income which could advantageously be used, and it is hoped that the present effort will speedily provide at least $100,000 of this amount.

The undersigned Committee confidently appeals to the citizens of Philadelphia for subscriptions to ensure the future great usefulness of the Institute, assured that the income from such a fund, devoted to its laudable purposes, will redound to the honor and credit of our city, and assist present and coming generations.

The Committee will be pleased to furnish any further information desired.

Subscription blanks may be obtained from the members of the Committee, or from the Actuary, at the Hall of the Institute, No. 15 South Seventh Street.

Very respectfully,

HENRY C. BROLASKY,
JOHN H. CONVERSE,
GEORGE V. CRESSON,
STEPHEN GREENE,
ALFRED C. HARRISON,
HERBERT M. HOWE, M.D.,
ALEXANDER KRUMBAHAR,
FRANK H. ROSENGARTEN,
JOSEPH M. WILSON, C.E.,
OTTO C. WOLF,

C. HARTMAN KUHN, *Chairman*,
*Committee on Endowment.*

# Mining and Metallurgical Section.

*Stated Meeting, March 9, 1898.*

## HISTORY OF THE PORTLAND CEMENT INDUSTRY IN THE UNITED STATES.

BY MR. ROBERT W. LESLEY.
Associate Am. Soc. C.E.

To the general public, cement is usually associated with the numerous works of the Romans, but, in point of fact, the mortars used in the Roman construction were not of cement at all, but were mixtures of slaked lime and pozzolana, a volcanic dust which was found in large quantities in Italy. It was not until the end of the last century that the true principles of hydraulic cement were discovered by Smeaton, who, in the construction of the Eddystone Light-House, made a number of experiments with the English limestones, and laid down, as a result, the principle that a limestone yielding from 15 to 25 per cent. of residue when dissolved in hydrochloric acid will set under water. These limestones he denominated hydraulic limestones, and from the principle so laid down by him come the two great definitions of what we now know as cement, namely, the natural and artificial cements of commerce.

The first class of cement, the natural, such as the Rosendale, Lehigh and Cumberland cements, was first made by Joseph Parker in 1796, who discovered what he called "Roman cement," based upon the calcination at low temperatures of the nodules found in the septaria geological formation in England. This was practically the first cement of commerce, and gave excellent results. Subsequent to the discoveries by Smeaton, General Sir William Paisley went into an exhaustive series of chemical and other tests to determine how artificial cements could be produced which would correspond to the higher grades of hydraulic limestones described by Smeaton and the Roman cement which

was then commanding the market. Contemporaneous with him and working in the same scientific field was Vicat, a French engineer, who conducted investigations of the same general character, and, in his book on hydraulic limestones and cements, describes his many experiments which led to the scientific development of a Portland cement artificially made by calcining mixtures of chalk and clays at high temperatures to incipient vitrefaction.

While these experiments were going on, Joseph Aspdin, a bricklayer or plasterer, took out a patent in England in 1824 on a high grade artificial cement, and, at great personal deprivation, succeeded in manufacturing it on a commercial scale by combining English chalks with clay from the river beds, drying the mixed paste, and after calcining at high heat the material thus produced, grinding it to powder. This cement, which was the first Portland cement in the market, obtained its name from its resemblance when it became stone to the celebrated Portland stone, one of the leading building materials in England.

The growth of the natural or Roman cement industry in England was more rapid than that of the Portland cement and in the early days of Portland cement that article was sold at prices considerably lower than those of the Roman cement manufactured by Parker and his successors in the business. It was not until many years after Smeaton's discovery that there was much growth in the Portland cement industry. A few works were started in England and a few more were started on the Continent by friends or relatives of Aspdin, but the demand was very slight, and there was a doubt in the minds of engineers as to the character of the material. Along in 1850, when the question of building the London drainage works came up, John Grant, the engineer, decided to use Portland cement in its construction, and his two papers, published by the Institute of Civil Engineers, form the first scientific literature on the subject of cement testing, and were the first to put Portland cement to the front as a material upon which engineers could rely to the fullest extent.

In this country we make the natural cements similar to

the Roman cement of Parker, and also the Portland cement of Aspdin. The laminated cement rock of the Lehigh region from which, among others, natural cement is made, is calcined in open kilns, like lime kilns, a moderate heat only being used. The product is then ground, put into barrels, and is ready for shipment.

The rocks used in the manufacture of Portland cement are very similar to those from which natural cement is made. The various layers in the natural rock may vary in size or stratification, so that the lime, alumina and silica may not be in position to combine under heat, or there may be too much of one ingredient, or not enough of the others in close proximity to each other. In making Portland cement these rocks, properly proportioned, are accordingly ground to an impalpable powder, the natural rock being broken down and the laminæ distributed in many small grains. This powder is then mixed with water, and is made into a new stone in the shape of the brick, or block, in which all the small grains formerly composing the laminæ of the original rock, are distributed and brought into a close mechanical juxtaposition to each other. The new rock thus made is put into kilns with layers of coke, and is then calcined at temperatures from 1,600° to 1,800°. The clinker, as it comes from the kiln, is then crushed and ground to an impalpable powder, which is the Portland cement of commerce. Portland cement may be made from other materials, such as chalk and clay, limestone and clay, cement rock and limestone and marls and clays. In every case the principle is the same, the breaking down and the redistributing of the materials so that the fine particles may be in close mechanical union when subjected to the heat of the kiln.

The first branch of the industry to develop in this country was that of natural cement, and its inception was largely because "necessity is the mother of invention." The first large public works built in this country were the canals, and the most necessary thing to build a canal was mortar that would hold the stones together at the locks, or walls, under water. Consequently, wherever canals were to be built, there was a search for cement rocks, and all the earliest works in this

country were established on the lines of canals. Thus, on the Chesapeake and Ohio Canal are the Cumberland and Round Top Works; on the Lehigh Canal the works at Siegfrieds and Coplay, Pa.; on the Richmond and Allegheny Canal, the works at Balcony Falls, Va.; on the Delaware and Hudson Canal the large group of works at Rosendale and Kingston; and on the Falls of the Ohio Canal, the large aggregation of works about Louisville. From this same fact grew the early package used in shipping cement in this country, the barrel, which was the package best adapted to water transportation, and it took many years, even since the railroads came, to overcome the prejudice for this form of package and to substitute the paper or duck bag for the barrel.

The growth of the natural cement industry has been very rapid, having increased from 3,000,000 barrels in 1882, to about 8,500,000 barrels in 1896. The first Portland cement made here involved a great cost of labor, and could not be offered at prices very much below the foreign article, and, as the Portland cement in a building costing $1,000,000 to $1,500,000 represented only a small percentage of the total cost, and as the difference between the American and the foreign article represented only a small percentage of this amount, it was almost impossible to convince engineers and architects that American Portland cement should be used. It is an interesting fact that among the first great works to use American Portland cement were the jetties built by Capt. James B. Eads, and among the first buildings in which American Portland cement was used was the Drexel Building, Philadelphia. By slow degrees, however, the prejudice in favor of the imported Portland was overcome and the American industry showed its right to exist.

The first American Portland cement plant was that of the Coplay Cement Company, of which Mr. David O. Saylor, of Allentown, was the President. This plant was established about 1865, and made natural cement of excellent quality. Mr. Saylor, who was a man of indomitable energy and great ability, made up his mind in the early seventies that he could make Portland cement in this country, and his first

experiments are most interesting. He knew that by burning to incipient vitrifaction the rocks of his quarry he could make a cement that at short periods showed tensile strains equal to the imported Portland, but he found this cement would crumble away as time went on, owing to the variation in the raw material. By sheer force of his native ability, Mr. Saylor studied out and successfully applied to the Lehigh rocks the principle above mentioned as governing the production of Portland cement, though he was dealing with a material never before used for the purpose. The process was that which I have just described, and is still in use in some of the largest works in the Lehigh district. Mr. Saylor's work was materially aided by Mr. John W. Eckert, a graduate of the Lehigh University, who became first the chemist and afterward the superintendent of the Coplay Cement Company, Mr. Saylor's concern at Coplay Station, which he subsequently left to join in the establishment of the American Cement Company.

While this experiment was being carried on to success in the Lehigh region, and the foundations were being laid for the large industry that now exists, a small works was erected near Kalamazoo, Mich., in 1872. Owing to the character of the material and the high cost of labor and fuel, this works made cement which was too expensive commercially and did not succeed. Early in 1875 works were started by Mr. Shinn at Wampun, Pa., near Pittsburg, using limestone and clay. These works are still going, though they have not been very materially increased since their inception. At South Bend, Ind., Thomas Millen, an Englishman, found a white marl and a blue clay which resemble in composition, though not quite in form, the materials used for cement making in England. He started a small works there in 1877, and the plant is still running, though in a moderate way. Mr. Millen later transferred his field of operations to New York State. The Rockland, Me., lime is well known as one of the best and purest in the country, and it was but natural that the Portland cement industry should seek a lodgment in that field. The Cobb Lime Company, an important concern there,

started works in 1879, but the product was too dear for commercial success, and they were closed down. For similar causes a similar fate overtook the National Cement Company, which was established by Mr. S. D. Coykendall and others on the Hudson, in the well-known natural Rosendale district. Thus it may be seen that out of the six original works started in this country prior to 1881, three were failures, and certainly the industry, with this percentage of loss, did not offer very encouraging outlook to the investor. At this period, the foreign Portland had the market exclusively, and there seemed little likelihood of growth for the American industry.

Patents were necessary to enlist capital in the earlier enterprises, and many of the earlier works were founded on them. The great difficulty in all the American enterprises seemed to be the cost of getting the raw material into powder, then into paste, then into bricks or blocks, and then into the kiln with a sufficient economy. About 1884 and 1885 patents were taken out by Messrs. James M. Willcox, E. J. Smedt and Robert W. Lesley for the purpose of mixing liquid hydrocarbons with the paste. In this way a "slurry" was made which, when compressed into balls or eggs, could be at once put into the kilns, and thus many of the intermediate steps of drying, etc., were dispensed with, and much labor and money saved. These processes, which were used in the works started by the American Cement Company at Egypt, Lehigh County, Pa., under the management of John W. Eckert and Robert W. Lesley, were based upon the use of the by-products of the manufacture of coal gas, but with the introduction of water gas and the consequent advance in the price of coal tar the processes were abandoned and other methods adopted. But the enterprise proved successful, and the Company now controls five large works, four at Egypt, Lehigh County, Pa., and one near Syracuse, N. Y., and is one of the largest producers of Portland cement in the country. While these methods of saving the intermediate processes of drying were being used, other inventions by Mathey, Navarro and Ransome in the same direction gave rise to the establishment of the Atlas

Portland Cement Company, which has two large works in the Lehigh region, and is another great producer of cement. These processes, based originally on the calcination of the crushed raw rock by oil in revolving kilns, were at first unsuccessful, the cement proving unreliable for the same reason that gave Saylor so much trouble originally. Subsequently, however, improvements were made whereby the material was ground to an impalpable powder and slightly moistened before being run through the kiln, and cement made in this way has proved successful, and is made in large quantities in this country.

The above gives a brief account of the development in this country from its inception to its present period of successful manufacture, and, as shown, the industry owes much to the application of American methods and American processes to a European industry. This leads to the discussion of the methods in use in this country and in Europe.

### THE HANDLING OF THE RAW MATERIALS.

*Materials.*—Portland cement in England and in Germany, which are the two largest producing countries, may broadly be stated to be the product of an intimate admixture of chalks and clays or marls and clays. The same condition may be stated to govern the industry in France, as most of the large works in that country use material of similar grade. Both of these materials containing large percentages of hydroscopic water, as well as water in mechanical combination, are treated in what is known as the wet way; by this is meant, that the making of the composition or slurry out of which the Portland cement is produced, is by the mixing of the two ingredients with a considerable portion of water, and in a large number of the European works this percentage of water is so large as to admit of the flowing of the material from place to place in the plant. The production of this intimate mixture of the raw materials in Europe is conducted in pug-mills or slurry-mills of various models, in some cases rollers running over the mixture of clay and chalk and reducing the material to uniform consistency, or in other cases the material being run through millstones in

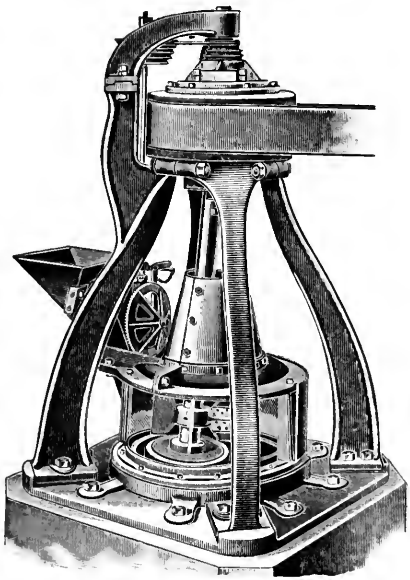
a wet condition. The material thus reduced was, under the old-time methods in Europe, run into immense settling-basins or vats, covering in some cases many acres, where it was allowed to settle, and where, by evaporation and decantation, it became a mud, showing, after drying, on its surface cracks such as are seen in disused brickyards or pond bottoms where the water has been drawn away. This material, broken up into lumps according to the cracks formed upon the surface, was brought to drying floors, and, after some few days of drying, was put into a kiln with coke and burned to incipient vitrifaction, producing clinker, which was subsequently ground to powder and produced the Portland cement of commerce. Of late years the better practice, which was first instituted in some of the French and better German works, is to more intimately grind the raw materials together, and while in a fluid state to run them into what are called *bassins de dosage*, where a sufficient supply can be held on hand to enable a careful examination to be made of the chemical constituents of the slurry, and from which basins the material is run into other settling-basins, whence it is taken to drying floors, or is pumped into tunnels or on to drying floors forming part of the kilns themselves. As contradistinguished from these processes, which in olden times took several months and under more modern processes in Europe occupy several days and in some cases several weeks, the American practice has been to use dry materials, such as the hydraulic cement, water limestones and lime-rocks of the Lehigh district, and to treat the material in practically a dry way, grinding it together in the form of powder, which is analyzed, and which powder is subsequently made into bricks by machinery or by hand, as stated in the historical portion of this article. Other works dealing with rocks such as are found at Glen Falls, N. Y., and in the New Jersey district near Phillipsburg, use practically the same methods, while mills dealing with marls and clays or wet materials are beginning to run them directly after mixing into *bassins de dosage* and thence into revolving kilns. Thus American practice is enabling mills to manufacture cement by greater econo-

mies in handling the raw materials as a primary and most important step.

*Kilns.*—Following, therefore, upon this step, the next step to be considered in American practice is that of the kilns, the principal distinctly American kiln in its use being the rotary kiln, already mentioned and which is an adaptation of the English Ransome kiln. This form of kiln was never successfully used in England, and it remained for the Americans to make a commercial success of it. Many of the works using the dry raw materials, however, are also enabled to successfully meet competition by the use of the dome kilns, such as are used in many of the European works, while others use what are known as the Dietsch and Schoefer continuous kilns, both of which are of German origin, and, while affording economy in coal, seem to entail larger labor cost than the use of the dome kilns. Others, as above stated, using the rock of the Lehigh district and also the marls and clays of the Ohio and Michigan districts, have found means of introducing the raw materials finely ground, into rotary kilns, either in a dry or wet condition. In its course from the receiving end of the kiln the damp powder or the slurry is relieved by the heat produced by either oil or pulverized coal from its moisture and carbonic acid gas, until finally the heating power of the kiln further along in its course, clinkers it, and at the discharging end of the kiln the material comes out in the form of small nodules of various sizes and shape and in a clinkered form. This does away with the making of bricks and other forms for the kilns in the case of wet raw material. The forms of these various kilns are very fully described in a new book by Dr. Schoch on the manufacture of cement, published under the auspices of the German Society of Cement Manufacturers, and in a new book by Candlot, Paris, 1897, a thorough description of which burning apparatus would involve considerable in the way of illustration and in technical explanation.

*Mills and Crushing Machinery.*—Another material point of the difference between the American and European methods, and one to which the very great advance in the product

of this country is due, is in the mechanical apparatus for grinding. European practice has been very largely based upon precedents. The precedents for mills were water-power, and the line shaft for driving mills was usually connected with a water-wheel, and mills were in turn connected with the line shaft by bevels or other forms of cog gearing. Thus the mills in many European works are situated in the second story of the buildings, losing considerable space, and the grinding apparatus in use are the well-known forms of millstones, varying in size from 3 to 6 feet in diameter. In many of the more advanced European plants mills are now driven directly by belts from line-shaft belt, thus taking the place of the old-fashioned cog gearing, and in several of the more modern mills what are known as tube-mills are being used, the apparatus consisting of a revolving cylinder containing a large number of Iceland pebbles. Into this cylinder the clinker is introduced, and, by the revolution of the cylinder and agitation of the pebbles, the material is ground to almost impalpable fineness. Early in the history of the Lehigh district in this country, millstones directly driven by belts and encased in iron frames marked an advance in American grinding methods. This was followed by the introduction in this and other districts of the Sturtevant, Frisbie-Leukop and other forms of iron and steel grinding apparatus, doing away with millstones. Another improvement in American grinding apparatus in this country dates possibly to the introduction of the Griffin mills by the works of the American Cement Company, at Egypt, Pa., somewhere about 1887. This mill is now largely



Griffin Mill.

in use in cement works in this country and abroad, its introduction in European works being very extensive during the past two or three years. The apparatus, as shown by the cut, is very simple in construction, and to it and the other iron mills is due much of the reputation American cement has, of late years, for its extreme fineness and sand-carrying qualities. American Gates crushers and coffee-mill crushers have also shown their superiority, according to the best reports, over similar machinery used in Europe, and in this line the modern works here seem fully equal, if not superior, to many of the leading European works, so far as crushing machinery goes. Having thus noted the differences in the handling of the raw materials, in kilns, and crushing machinery between American and European works making Portland cement, it is next of importance to examine the *American raw materials*, and to note that, notwithstanding their variation in many cases from the raw materials of Europe, that American Portland cement produced from these comes up, in both *chemical analysis* and *standard* tests, to the highest grade of the old-established European brands of Germany, France and England.

## AMERICAN RAW MATERIALS.

In the United States raw materials for Portland cement may be said to be very numerous and quite varied. The principal of all the deposits, and the one from which the largest amount of cement is turned out, may be said to be that of the Lehigh hydraulic limestones, above stated, which are found on either side of the Lehigh River, at or around Coplay, and which extend for a considerable distance, and are found farther down across the Delaware, near Phillipsburg, N. J. These rocks are laminated water lime rocks, and by reason of their chemical composition, as well as their structural character are specially adapted to the manufacture of Portland cement. They form a part of what is known as the Silurian argillaceous limestones, a formation which also forms cement rocks for many of the other cement districts. The Glen Falls cement which is made at Glen Falls, N. Y., is made from a lime rock of the Silurian formation, together with clay or clay rock found in

the same vicinity. In New York State, at and around Jordan, Warners and Wayland, the principal ingredient is the white marl of the Silurian formation, while similar materials are also used in the manufacture of cement in the Michigan and Ohio districts. Further west, at San Antonio, Tex. White Springs, Ark., and Yankton, S. D., Portland cement is made from the cretaceous rocks which are found outcropping at various points there and throughout a large territory in the middle West. These with clay, produce excellent cement.

Grouped according to districts and the raw material found therein, the American Portland cement industry may be said to embrace:

(1) *The Lehigh district*, with a total product, according to the figures for 1897, of 1,640,000 barrels, or nearly 75 per cent. of the total output of the country. It extends along the Lehigh River from Siegfried, Pa., to Phillipsburg, N. J., and includes the four mills of the American Cement Company, at Egypt; the two mills of the Coplay Cement Company, at Coplay; the two mills of the Atlas Cement Company, at Coplay and Northampton; the mill of the Hercules Rock Lock and Bonnville Companies at Whitehall and Siegfried, and the mills of the Alpha and Vulcanite Companies, near Whittaker, N. J.

(2) The New York district, embracing the marl and clay raw material plants of the Empire and American Cement Companies, at Warners and Jordan, and the Wayland and the Whittemore, Rauber & Vicinus Works, near Wayland. In addition to these is the Glen Falls (N. Y.) Portland Cement Works, using rock materials.

(3) The Ohio district, including works at Sandusky and Castalia, O., operated by companies of the same name, and using marls and clays, while rock materials are used by the Diamond Cement Company at Middle Branch.

(4) The South Dakota district, with the works of the Yankton Portland Cement Company, using a species of chalk and clay.

The following table, from the "Mineral Industry of the United States," Vol. VI, gives the latest figures on the production of the various districts. The Michigan district uses marl and clay, and several works are going into opera-

tion there, among them the Bronson and the Peerless; the Arkansas district is limited to a single works, at Chalk Cliffs; the Illinois, to a single works, near Chicago, which was recently burnt down; the Texas region to one works, near San Antonio; the Utah, to a single works, near Salt Lake, also recently burnt, and the California, to two small works, at San Diego and Colton, respectively:

PRODUCTION OF PORTLAND CEMENT IN THE UNITED STATES.

(*In Barrels of 400 Pounds.*)

| States. | 1896. | | | 1897. | | |
|---|---|---|---|---|---|---|
| | | Value at Works. | | | Value at Works. | |
| | Barrels. | Total. | Per Barrel. | Barrels. | Total. | Per Barrel. |
| California | 8,985 | $17,970 | $2 00 | 17,060 | $51,180 | $3 00 |
| New Jersey | 270,858 | 400,999 | 1 48 | 440,454 | 641,421 | 1 45 |
| New York | 266,482 | 445,594 | 1 67 | 361,994 | 592,676 | 1 64 |
| Ohio | 163,182 | 320,364 | 1 96 | 147,332 | 291,640 | 1 98 |
| Pennsylvania | 825,000 | 1,225,000 | 1 49 | 1,200,000 | 1,740,000 | 1 45 |
| South Dakota | 23,776 | 47,552 | 2 00 | 39,900 | 75,8 0 | 1 90 |
| Texas | 15,000 | 38,000 | 2 53 | 7,778 | 19,912 | 2 56 |
| Other States (*a*) | 4,000 | 7,000 | 1 75 | 58,453 | 108,850 | 1 86 |
| Total barrels | 1,577,283 | $2,502,479 | $1 59 | 2,272,971 | $3,521,489 | $1 55 |

(*a*) Includes Arkansas, Illinois, Michigan and Utah.

## CHEMICAL ANALYSIS.

The chemical analysis of the American cements, while dealing with materials of different structural character than those which are used abroad, may be said to compare most favorably with the chemical analysis of the European product. It is a well-known fact that the chemical analysis of Portland cement may vary largely in many of its ingredients, owing to the particular kind of materials out of which it is made and their action under the flame of the kiln, but an examination of the table which follows will show that American Portland cements show no material difference from the better grades of the European brands.

The following table gives representative analyses of a number of American Portland cements:

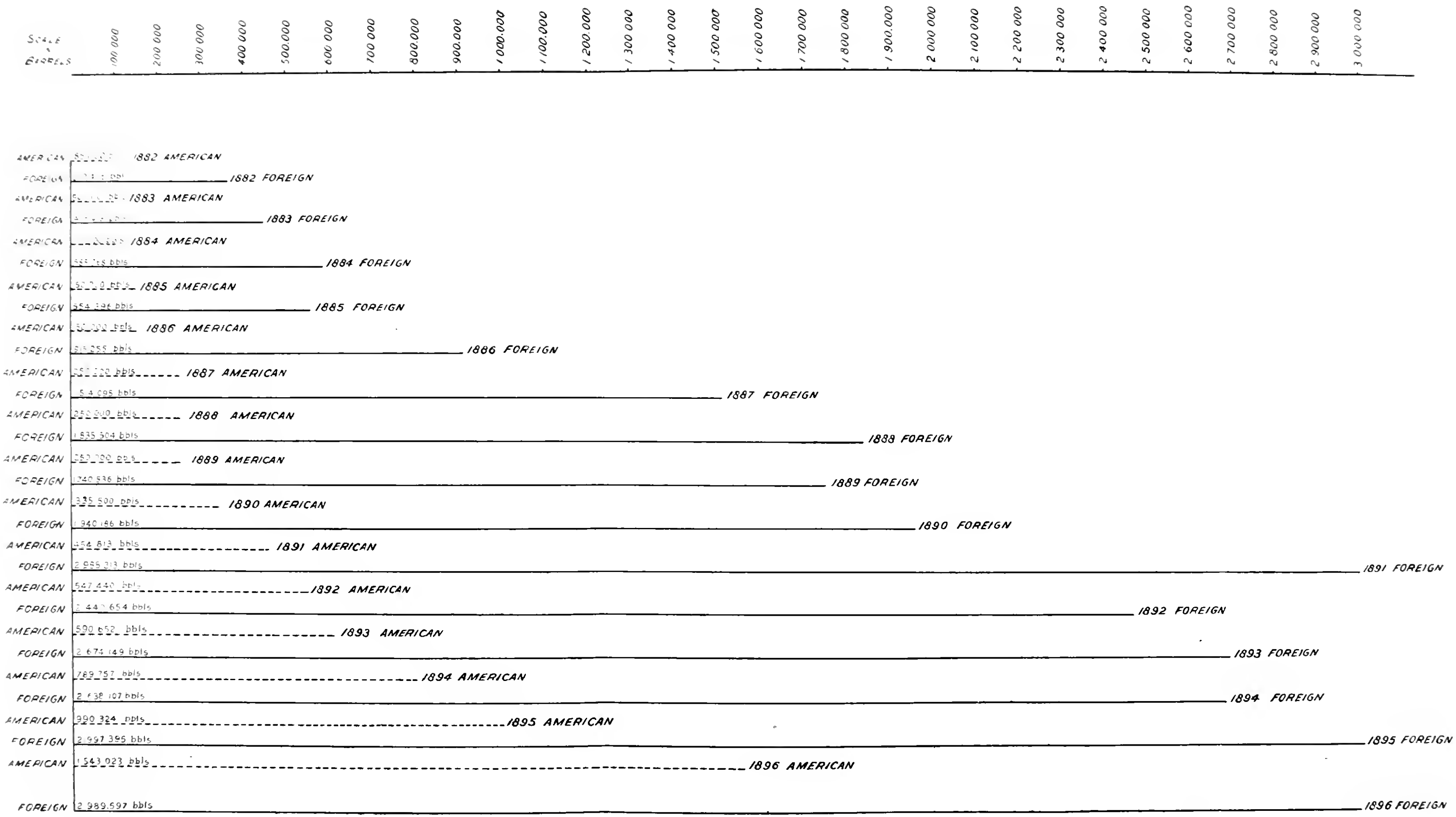



Table of American Production of Portland Cement 1882–1896 compared with Imports Foreign Portland Cement.

LONG-TIME TESTS ON "GIANT" PORTLAND CEMENT.

| BRAND "Giant" Portland | Mode of Mixing. | 1 Day | | 1 Week | | 1 Mo. | | 3 Mos. | | 6 Mos. | | 9 Mos. | | 1 Year | | 15 Mos. | | 18 Mos. | | 2 Years | | 3 Years | | 4 Years | | 5 Years | | 6 Years | | 7 Years | | 8 Years | | 9 Years | | Fineness. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Number of Briquettes. | Average, in pounds. | Residue on No. 50 sieve, 2,500 holes to sq. in. | Residue on No. 74 sieve, 5,180 holes to sq. in. | Residue on No. 100 sieve, 10,000 holes to sq. in. |
| * Sodom and Bog Brook Dams, New York Aqueduct. About 50,000 bbls. | Neat | 1,025 | **140** | 1,398 | **348** | 220 | **422** | 180 | **540** | 100 | **634** | 30 | **638** | 180 | **682** | 30 | **687** | 110 | **672** | 110 | **694** | 90 | **736** | 60 | **771** | *4 | **646** | *6 | **583** | *2 | **585** | 2 | **749** | 2 | **817** | ... | ... | **18.0** |
| | 2 to 1 | ... | ... | 220 | **166** | 120 | **280** | 140 | **364** | 84 | **468** | 50 | **468** | 90 | **490** | 36 | **526** | 100 | **530** | 100 | **564** | 130 | **680** | 120 | **674** | | | | | | | | | | | | | |
| | 3 to 1 | ... | ... | 226 | **140** | 140 | **234** | 112 | **350** | 110 | **428** | 30 | **428** | 240 | **420** | 40 | **500** | 80 | **514** | 80 | **512** | 160 | **572** | ... | ... | *4 | **486** | *5 | **491** | *1 | **618** | | | | | | | |
| Titicus Dam, New York Aqueduct. About 100,000 bbls. | Neat | 3,448 | **157** | 4,165 | **380** | 637 | **476** | 505 | **529** | 478 | **575** | 479 | **599** | 350 | **642** | 181 | **594** | 135 | **584** | 137 | **641** | 62 | **668** | 54 | **699** | 64 | **704** | 6 | **647** | ... | ... | ... | ... | ... | ... | ... | ... | **11.7** |
| | 2 to 1 | ... | ... | 2,934 | **200** | 424 | **317** | 281 | **450** | 321 | **491** | 278 | **532** | 219 | **549** | 157 | **557** | 92 | **541** | 52 | **536** | 37 | **573** | 13 | **565** | 38 | **610** | 5 | **631** | | | | | | | | | |
| | 3 to 1 | ... | ... | 1,604 | **115** | 260 | **185** | 450 | **289** | 133 | **347** | 146 | **311** | 132 | **426** | 70 | **424** | 66 | **416** | 126 | **419** | 7 | **483** | 56 | **539** | 42 | **540** | 5 | **611** | | | | | | | | | |
| Carmel and Craft's Dams, New York Aqueduct. About 40,000 bbls. | Neat | 1,786 | **140** | 1,075 | **343** | 324 | **443** | 551 | **517** | 529 | **548** | 491 | **568** | 289 | **617** | ... | ... | 273 | **604** | 211 | **611** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | **14.7** |
| | 2 to 1 | ... | ... | 1,642 | **182** | 216 | **308** | 85 | **445** | 87 | **480** | 76 | **472** | 43 | **585** | ... | ... | 49 | **477** | 55 | **475** | 3 | **538** | | | | | | | | | | | | | | | |
| | 2 to 1 from Mortar Box | ... | ... | 61 | **164** | 51 | **237** | 8 | **385** | 11 | **494** | 8 | **491** | 7 | **367** | ... | ... | 12 | **516** | 3 | **568** | | | | | | | | | | | | | | | | | |
| | 3 to 1 | ... | ... | 13 | **100** | 13 | **174** | 7 | **319** | 12 | **372** | 11 | **398** | 10 | **413** | ... | ... | 8 | **401** | 10 | **406** | | | | | | | | | | | | | | | | | |
| | 3 to 1 from Mortar Box | ... | ... | 45 | **112** | 31 | **166** | 6 | **310** | 8 | **480** | 7 | **500** | 9 | **541** | ... | ... | 7 | **437** | 5 | **406** | | | | | | | | | | | | | | | | | |
| Reading Terminal Railroad and Station, Philadelphia. About 80,000 bbls. | Neat | ... | ... | 329 | **315** | 267 | **376** | 69 | **451** | 15 | **549** | 16 | **576** | 10 | **523** | 1 | **640** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | **.090** | **10.04** | **14.79** |
| | 3 to 1 | ... | ... | 536 | **79** | 431 | **129** | 104 | **174** | 20 | **228** | 15 | **225** | 47 | **261** | 5 | **287** | | | | | | | | | | | | | | | | | | | | | |
| | 2 to 1 from Mortar Box | ... | ... | 190 | **84** | 180 | **144** | 17 | **219** | 13 | **234** | 25 | **281** | 62 | **325** | 12 | **417** | | | | | | | | | | | | | | | | | | | | | |
| Niagara Falls Tunnel, Niagara Power Co. 80,000 bbls. | Neat | ... | ... | 495 | **321** | 309 | **420** | 12 | **514** | 24 | **562** | ... | ... | 24 | **661** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | **14.9** |
| | 2 to 1 | ... | ... | 482 | **152** | 271 | **242** | 54 | **369** | 20 | **454** | ... | ... | 7 | **472** | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 to 1 | ... | ... | 527 | **98** | 399 | **177** | 143 | **254** | 181 | **301** | ... | ... | 12 | **391** | | | | | | | | | | | | | | | | | | | | | | | |
| Cornell Dam, New Croton Aqueduct. Largest masonry dam in the world About 65,000 barrels. | Neat | 2,677 | **186** | 2,699 | **413** | 405 | **525** | 190 | **559** | 110 | **600** | 120 | **601** | 105 | **679** | 55 | **713** | 53 | **679** | 36 | **722** | | | | | | | | | | | | | | | | | |
| | 2 to 1 | ... | ... | 2,624 | **303** | 415 | **432** | 180 | **558** | 110 | **664** | 110 | **663** | 90 | **707** | 43 | **700** | 53 | **701** | | | | | | | | | | | | | | | | | | | |
| | 3 to 1 | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | 10 | **482** | 10 | **529** | 5 | **534** | | | | | | | | | | | | | | | | | | | |
| District of Columbia. Giant (Egypt). | Neat | ... | **188** | ... | **278** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | 3 to 1 | ... | ... | ... | **159** | ... | **205** | ... | **240** | ... | **341** | ... | **360** | ... | **394** | ... | ... | ... | ... | ... | **417** | | | | | | | | | | | | | | | | | |
| Metropolitan Water Board of Boston, Mass. Over 15,000 barrels. | Neat | 1,510 | **293** | 617 | **453** | 40 | **486** | 20 | **540** | 5 | **567** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | **1.0** | ... | **9.8** |
| | 2 to 1 | ... | ... | 616 | **282** | 40 | **339** | 20 | **438** | 5 | **549** | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Department of Public Works, Philadelphia, Pa. Giant. Over 20,000 barrels. | Neat | ... | **249** | 412 | **500** | ... | ... | ... | ... | ... | **592** | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | ... | **1.3** | ... | **8.6** |
| | 3 to 1 | ... | **89** | ... | **175** | ... | **252** | ... | ... | ... | **311** | | | | | | | | | | | | | | | | | | | | | | | | | | | |

* NOTE.—Up to 4 years briquettes at Sodom were broken in the Laboratory on the Dam. Subsequently they were broken at Cornell Dam, after having been out of water for some months, between October, '93, and June, '94, which explains the temporary falling off.

| Brand of Cement. | $SiO_2$ Per Cent. | $Al_2O_3$ Per Cent. | $Fe_2O_3$ Per Cent. | CaO Per Cent. | MgO Per Cent. | $SO_3$ Per Cent. | Authority. |
|---|---|---|---|---|---|---|---|
| Alpha . . . . . . | 22·62 | 8·76 | 2·66 | 61·46 | 2·92 | 1·52 | Booth, Garret & Blair. |
| Atlas . . . . . . . . | 21·96 | 8·29 | 2·67 | 60·52 | 3·43 | 1·49 | " " " |
| Giant . . . . . . . . | 19·92 | 9·83 | 2·63 | 60·32 | 3·12 | 1·13 | " " " |
| Saylors . . . . . . . | 22·68 | 6·71 | 2·35 | 62·30 | 3·41 | 1·88 | " " " |
| Vulcanite . . . . . | 21·08 | 7·86 | 2·48 | 63·68 | 2·62 | 1·25 | " " " |
| Empire . . . . . . | 22·04 | 6·45 | 3·41 | 60·92 | 3·53 | 2·73 | " " " |
| Jordan . . . . . . . | 21·86 | 7·17 | 3·73 | 61·14 | 2·34 | 1·94 | " " " |
| Diamond . . . . . . | 21·80 | 7·95 | 4·95 | 61·90 | 1·64 | 0·79 | " " " |
| Sandusky . . . . . | 23·08 | 6·16 | 2·90 | 62·38 | 1·21 | 1·66 | " " " |
| Bronson . . . . . . | 20·95 | 9·74 | 3·12 | 63·17 | 0·75 | 0·86 | Mfr.'s Analysis. |
| White Cliffs, Ark. . | 22·93 | *10·33 | | 64·67 | 0·94 | 1·05 | " " |

* Alumina and iron together.

For comparison, the following analyses of European cements are given :

| Brand of Cement. | $SiO_2$ Per Cent. | $Al_2O_3$ Per Cent. | $Fe_2O_3$ Per Cent. | CaO Per Cent. | MgO Per Cent. | $SO_3$ Per Cent. | Authority. |
|---|---|---|---|---|---|---|---|
| White Label, Alsen . | 20·48 | 7·28 | 3·88 | 64·30 | 1·76 | 2·46 | Booth, Garret & Blair. |
| Dyckerhoff . . . . . | 20·64 | 7·15 | 3·69 | 63·06 | 2·33 | 1·39 | " " " |
| Germania . . . . . | 22·08 | 6·84 | 3·36 | 63·72 | 1·32 | 1·82 | " " " |
| Hemmoor . . . . . | 21·14 | 6·95 | 4·01 | 63·24 | 1·44 | 1·47 | " " " |
| Lagerdorfer . . . . | 23·55 | 7·47 | 2·40 | 61·99 | 1·42 | 1·07 | " " " |
| B. Shoobridge Co. . | 22·20 | 7·35 | 4·77 | 61·46 | 1·35 | 1·86 | " " " |
| Francis . . . . . . | 22·18 | 8·48 | 5·08 | 61·44 | 1·34 | 1·56 | " " " |
| Condor . . . . . . | 23·87 | 6·91 | 2·27 | 64·49 | 1·04 | 0·88 | " " " |
| Condlot, French . . | 22·30 | 8·50 | 3·10 | 62·80 | 0·45 | 0·70 | Candlot. |
| Boulogne, French . | 22·30 | 7·00 | 2·50 | 64·62 | 1·04 | 0·75 | " |

(From the "Mineral Industry of the United States," Vol. VI.)

## TESTING OF AMERICAN PORTLAND CEMENT.

For purposes of comparison between the cement of American and European manufacture, tables are given herewith of results of tests on a number of brands in actual use on the Nashua Aqueduct of the Metropolitan Water System, of Boston, Mass., and the public work of the United States Government in the District of Columbia.

FROM REPORT ENGINEER DEPARTMENT OF THE DISTRICT OF COLUMBIA FOR UNITED STATES GOVERNMENT FOR YEAR ENDING JUNE 30, 1897.

| Brand of Portland Cement. | Tensile Strength. Neat. 1 Day. | Neat. 7 Days. | 3 Parts Quartz. 7 Days. | 3 Parts Quartz. 1 Month. | 3 Parts Quartz. 6 Months. | 3 Parts Quartz. 1 Year. | 3 Parts Quartz. 2 Years. |
|---|---|---|---|---|---|---|---|
| Alpha, "American" | — | — | 105 | 182 | 327 | 350 | — |
| Alsen | 292 | 635 | 188 | 310 | 390 | 366 | 371 |
| Atlas, "American" | 432 | 768 | 321 | 441 | 538 | 546 | 523 |
| Dufossez and Henry, "Belgian" | 149 | 546 | 159 | 188 | 319 | 332 | 335 |
| Dyckerhoff, "German" | 345 | 566 | 164 | 175 | 298 | 323 | 370 |
| Egypt, "American" | 188 | 278 | 159 | 205 | 341 | 394 | 417 |
| Giant, "American" | 160 | 495 | 230 | 275 | 325 | 327 | 342 |
| Hannover, "German" | 295 | 571 | 205 | 244 | 315 | 354 | — |
| Hemmoor, "German" | 295 | 657 | 159 | 203 | 314 | 347 | 355 |
| Mannheimer, "German" | 329 | 525 | 193 | 226 | 343 | 336 | — |
| Porta, "German" | 407 | 415 | 181 | 257 | 343 | 329 | 349 |
| Saylor, "American" | 201 | 461 | 135 | 156 | 289 | 279 | — |

REPORT 1897 ENGINEER NASHUA AQUEDUCT, BOSTON METROPOLITAN WATER BOARD.

| Brand. | Composition of Briquette. | Fineness. Per Cent. Residue on No. 50 Sieve, 2,500 Meshes to Sq. Inch. | Per Cent. Residue on No. 100 Sieve, 10,000 Meshes to Sq. Inch. | Per Cent. Residue on No. 180 Sieve, 32,400 Meshes to Sq. Inch. | Tensile Strength. 1 Day. Pounds Per Sq. Inch. | 7 Days. Pounds Per Sq. Inch. | 28 Days Pounds Per Sq. Inch. | 3 Mos. Pounds Per Sq. Inch. | 6 Mos. Pounds Per Sq. Inch. | 1 Year. Pounds Per Sq. Inch. |
|---|---|---|---|---|---|---|---|---|---|---|
| Atlas, "American" | Neat | ·4 | 9·9 | 24·7 | 392 | 677 | 712 | 729 | 792 | — |
| | 2 to 1 | — | — | — | — | 325 | 356 | 342 | 346 | — |
| Brooks, Shoobridge, "English" | Neat | 1·0 | 11·4 | 26·0 | 184 | 443 | 442 | 527 | 585 | 691 |
| | 2 to 1 | — | — | — | — | 255 | 311 | 398 | 424 | 490 |
| Giant, "American" | Neat | 1·0 | 9·8 | 21·8 | 293 | 453 | 486 | 540 | 567 | — |
| | 2 to 1 | — | — | — | — | 282 | 339 | 438 | 549 | — |
| Iron-clad, "American" | Neat | ·3 | 8·5 | 26·0 | 404 | 537 | 535 | 604 | 714 | — |
| | 2 to 1 | — | — | — | — | 323 | 354 | 400 | 409 | — |
| Settin, Girstower, "Gertman" | Neat | 2·8 | 17·9 | 30·9 | 288 | 570 | 596 | 646 | 674 | 666 |
| | 2 to 1 | — | — | — | — | 373 | 361 | 379 | 372 | 402 |
| West Kent, "English" | Neat | 1·7 | 18·6 | 31·1 | 178 | 356 | 456 | 524 | 547 | 588 |
| | 2 to 1 | — | — | — | — | 261 | 326 | 410 | 534 | 547 |
| Total | Neat | ·8 | 10·7 | 24·7 | 321 | 517 | 552 | 588 | 623 | 628 |
| | 2 to 1 | — | — | — | — | 295 | 341 | 393 | 416 | 491 |

These tables show that in fineness American Portlands considerably excel the imported brands, and also excel them in neat and sand mortars in many cases at both short and long time tests.

In reply to the one vital question which may be asked of the American Portland cement manufacturer—will your cement stand the test of time?—the following table, showing a record on nearly half a million barrels of one American Portland cement up to periods of from one to nine years, shows that American Portland cement meets all the requirements of stability and permanence, and has, in fact, "come to stay."

## GROWTH OF THE INDUSTRY.

THE GROWTH OF THE INDUSTRY may be best illustrated by the accompanying photograph, which shows a series of cement barrels, each barrel representing the American product of Portland cement for a certain year, as shown by the report of the United States Geological Survey of 1896. These differences are shown by the *height* of the barrel only, the scale being that of *height* and not *cubical* contents of the several barrels, but the relative *height* of the barrel will give to the eye a thorough impression of how the production of American cement has grown within the past fifteen years. Possibly a better method, however, of arriving at the growth of the American industry is afforded by an examination of the photograph which is shown below, in which the American output and the foreign imports are by years grouped together, and indicated by straight and dotted lines. This conveys to the eye the growth of the American product.

The figures are those of the United States Geological Survey and show how rapidly the American production of Portland cement is overtaking the importation of the foreign article.

It can be readily seen by the above that the percentage of American Portland to the imported is steadily rising, and while the figures for 1897 of the United States Geological Survey are not yet ready, the "Mineral Industry" for 1897

Year, 1882 1890 1891 1892 1893 1894 1895 1896

TABLE SHOWING BY COMPARATIVE HEIGHT OF A CEMENT BARREL, THE GROWTH OF THE AMERICAN PORTLAND CEMENT INDUSTRY.

shows that, practically, the American production has overtaken the importation of the foreign article.

They are as follows:

1897. BARRELS OF 400 POUNDS.

| | Barrels. |
|---|---|
| American Production . . . . . . . . . . . . . . . . . . . | 2,272,971 |
| Importation foreign cement . . . . . . . . . . . . . . . | 2,090,760 |

The following table shows the products, imports, exports and consumption of all grades of cement, natural and Portland, for the past five years for "Mineral Industry of the United States." The figures vary slightly from those of the United States Geological Survey.

CEMENT PRODUCTION, IMPORTS, EXPORTS, AND CONSUMPTION IN THE UNITED STATES.

(In Barrels of 300 Pounds.)

| Year. | Production. | | | | Imports. | | Exports. | | Consumption. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Natural Hydraulic. | Portland. | Total Barrels. | Value. | Barrels. | Value. | Barrels. | Value. | Barrels. | Value. |
| 1892 . . . | 8,211,181 | 547,440 | 8,758,621 | $7,152,750 | 3,254,183 | $3,378,824 | 107,894 | $169,538 | 11,905,000 | $10,361,543 |
| 1893 . . . | 7,445,950 | 673,989 | 8,119,939 | 6,063,131 | 3,565,532 | 3,470,169 | 112,518 | 174,663 | 11,573,451 | 9,358,737 |
| 1894 . . | 7,595,259 | 738,196 | 8,633,455 | 5,478,051 | 3,540,820 | 3,396,729 | 120,967 | 180,881 | 12,137,955 | 8,859,708 |
| 1895 . . . | 7,694,053 | 998,745 | 8,692,798 | 6,027,374 | 3,996,520 | 3,873,123 | 95,559 | 131,541 | 12,676,798 | 9,931,572 |
| 1896 . . | 7,407,311 | 2,103,044 | 9,510,355 | 6,888,441 | 3,561,160 | 3,394,426 | 69,632 | 103,315 | 12,195,959 | 9,369,700 |
| 1897 . . . | 7,781,377 | 3,030,628 | 10,812,005 | 7,648,613 | 7,787,760 | 2,688,122 | 61,759 | 103,389 | 13,538,006 | 10,233,346 |

The growth of the consumption of cement given by periods of ten years is as follows:

| Year. | Pounds per capita. |
|---|---|
| 1850 . . . . . . . . . . . . . . . . . . . . . . . . . . | 6·46 |
| 1860 . . . . . . . . . . . . . . . . . . . . . . . . . . | 10·49 |
| 1870 . . . . . . . . . . . . . . . . . . . . . . . . . . | 12·77 |
| 1880 . . . . . . . . . . . . . . . . . . . . . . . . . . | 13·04 |
| 1890 . . . . . . . . . . . . . . . . . . . . . . . . . . | 33·93 |

Generally, therefore, it may be safely said that the cement industry is growing rapidly, but most especially is this the case with the manufacture of Portland cement, the production of which this year is expected to largely exceed the importations.

It seems only a question of time when the American Portland will ultimately supersede in most of our home markets the foreign article. The manufacture may be said now to be an established industry in the United States, and one deserving the success that it has shown its right to have. Its capabilities are very large, and its past has shown that its development will depend upon careful management, both scientific and practical, inasmuch as the successful works have won their success upon these elements, as well as upon their proper geographical location with regard to raw materials and proper distributing markets.

## DISCUSSION.

MR. RICHARD L. HUMPHREY.—I do not feel that I can contribute anything further on the industry of Portland cement. I have listened with a great deal of interest to what Mr. Lesley has said concerning the development of this industry. He is thoroughly conversant with this subject, and he has presented it to you in his usual clever style.

In the matter of testing cements I can add a few remarks which may perhaps be of interest. All cement used by the city of Philadelphia is subjected to careful inspection. The city consumes, each year, about 120,000 barrels of natural cement and about 50,000 barrels of Portland cement. For sewers, foundations for street pavements, etc., natural cement is used, while for the more important works, bridges, bulkhead walls and concrete in large masses, Portland cement is used. The natural cement to which I refer is not the natural cement referred to by Mr. Lesley, and which is usually known as Roman or Rosendale cement, but it is an improved or high-grade natural cement, fully 50 per cent. stronger than what is usually known as natural cement. For the class of work referred to, the city finds this cement to be durable and very economical.

Since my connection with the city, during which time the testing laboratory has been established and developed, there has been a gradual improvement in the quality of the cement submitted for use in public work.

This can be said to be due (1) to the maintenance of a testing laboratory and the enforcement of rigid tests, and (2) to improvements in the quality of the cement, due to improvements in the process of manufacture.

In 1892, where Portland cement was required, the city used almost exclusively foreign Portland cement. Each succeeding year witnessed a gradual improvement in the quality of American Portland cement, accompanied by a corresponding decrease in the consumption of foreign Portland cements.

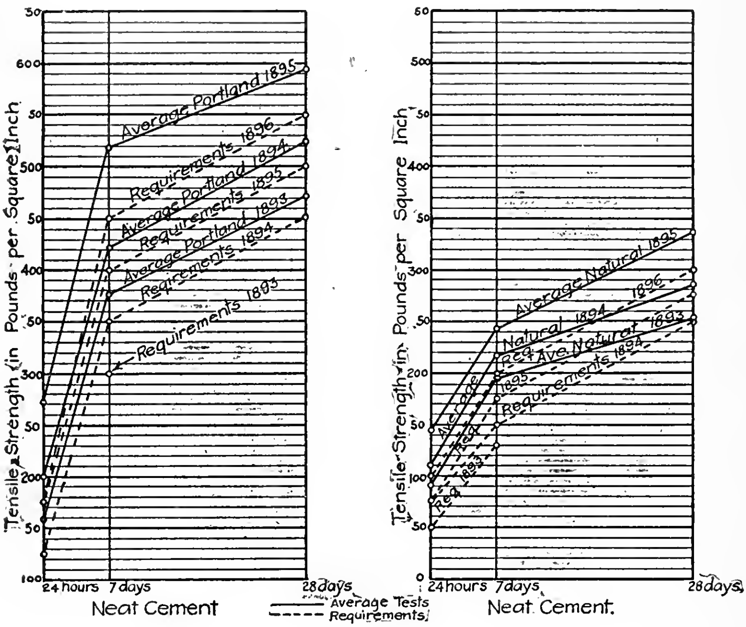
The average results of the tests made in the laboratory each year showed a marked improvement over the average results of the tests of the previous year, while for the last two or three years these tests show that the American cement is not only equal to the foreign cement in quality, but superior to it.

This improvement in the quality of the American cements has also been accompanied by a decrease in the price of the cement.

In 1892 high grade foreign Portland cement brought from $2.45 to $2.85 per barrel, while natural cements brought from $1.20 to $1.40 per barrel. These foreign cements were gradually supplanted by the high grade American cements, until in 1897, American Portland cement brought on an average $1.90 per barrel (in bags), and in some cases as low as $1.50 per barrel (in bags), while natural cement brought on an average 95 cents per barrel (in bags), and as low as 85 cents per barrel (in bags). Foreign Portland cement of the same grade ranged in price from $2.15 to $2.85 per barrel.

In 1892 the city required Portland cement, when tested neat, to yield a tensile strength of 300 pounds per square inch in seven days, while natural cement was required to show 120 pounds at the end of the same period of time. The specifications were increased each year, as was shown to be necessary by the average tests made during the year, until to-day the requirements are: for neat Portland cement 175 pounds in twenty-four hours, 500 pounds in seven days, and 600 pounds in twenty-eight days; for 1 part Portland

cement and 3 parts standard quartz sand, 170 pounds in seven days, 240 pounds in twenty-eight days. For natural cement the requirements are: neat, 100 pounds in twenty-four hours, 200 pounds in seven days, and 300 pounds in twenty-eight days; for 1 part natural cement and 2 parts standard quartz sand, 125 pounds in 7 days, and 200 pounds in twenty-eight days.

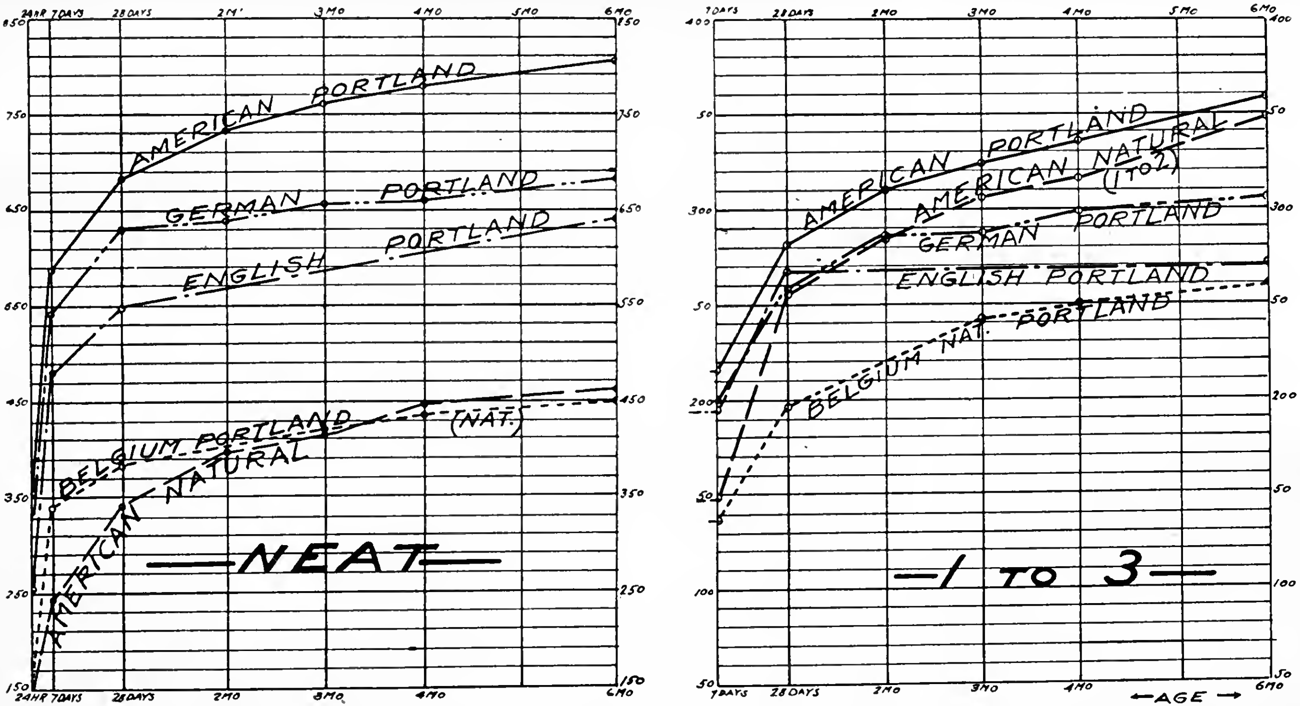



The city is using to-day cement over 50 per cent. stronger than that used during 1892, and at a cost of from 50 to 60 cents per barrel less. Nearly every barrel of this material is American cement.

This is certainly very creditable to the American cement manufacturers, and argues well for the future success and development of this industry.

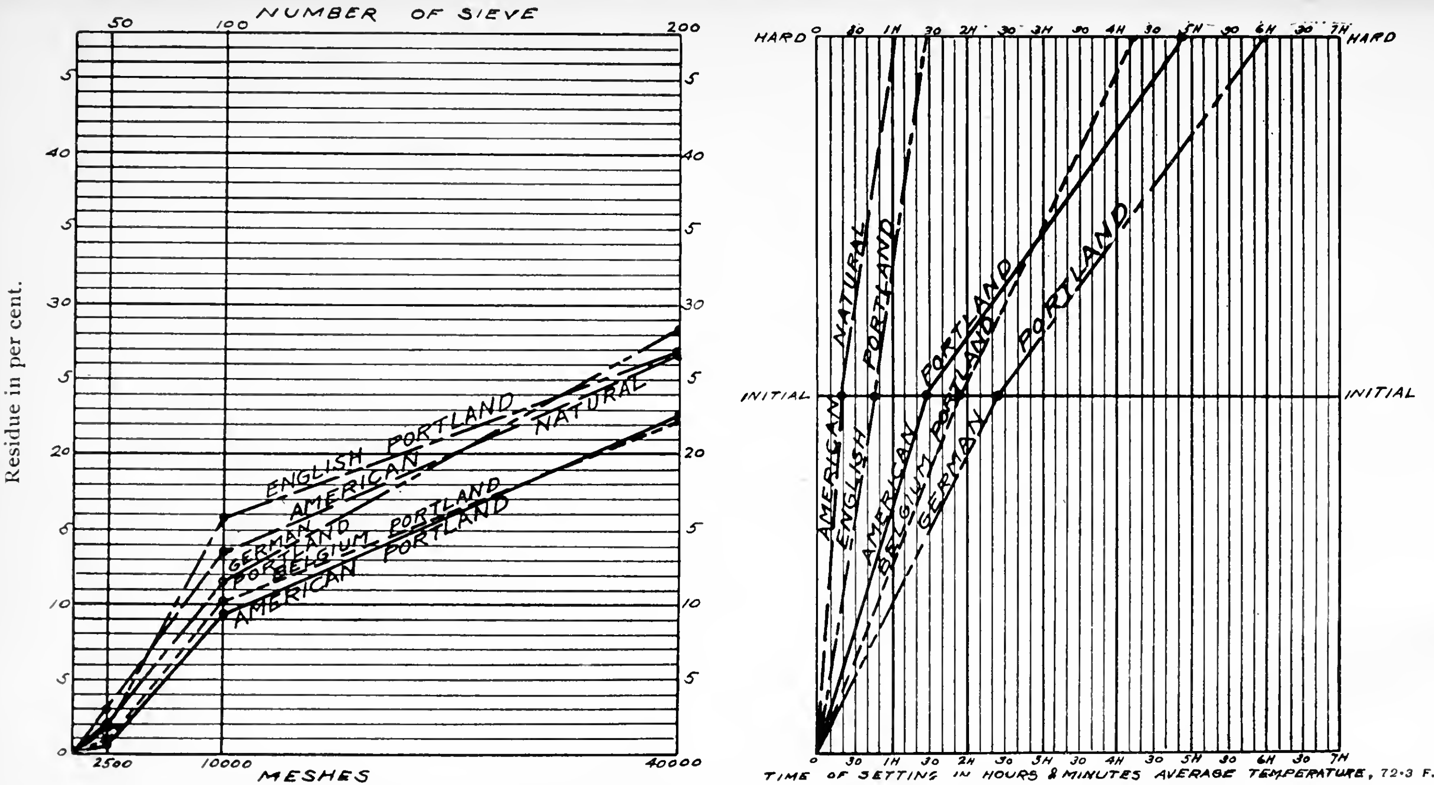
The development of the American Portland cement industry is another illustration of the fact, that when an industry is started in this country, American skill and ingenuity eventually succeed not only in equaling, but also,

Tensile strength in pounds per square inch.




— — — American Natural.
———— American Portland.
—- - —- - German Portland.
——-—— English Portland.
- - - - - - - Belgium Portland (Nat.).

Department of Public Works—Bureau of Surveys—Laboratory of Inspector of Cements—Diagram Showing Average Results of Tests of Cements—Neat and with Sand—Made in 1897.




— — — American Natural. ——- - -—- - - German Portland. - - - - - - - Belgian Portland.
———— American Portland. —- - —- - - English Portland.

Department of Public Works—Bureau of Surveys—Laboratory of Inspector of Cements—Average Results of Tests—for Fineness and Time of Setting—Made in 1897.

DEPARTMENT OF PUBLIC WORKS—BUREAU OF SURVEYS.

LABORATORY OF THE INSPECTOR OF CEMENTS.

*Requirements of Specifications for Cement for Years 1893 to 1897.*

| Year. | Portland Cement. | | | | | | | | | | | | | | | | Natural Cement. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Fineness. Per Cent. of Residue on Sieve. | | | Time of Setting in Minutes. Temperature 60°–70° F. | | Ultimate Tensile Strength in Pounds Per Square Inch. | | | | | | | | | | | Fineness. Per Cent. of Residue on Sieve. | | | Time of Setting in Minutes. Temperature 60°–70° F. | | Ultimate Tensile Strength in Pounds Per Square Inch. | | | | | | | | |
| | | | | | | Neat. | | | Standard Sand. 1 to 3. | | Mixing Box. | | | | | | | | | | | Neat. | | | Standard Quartz Sand. | | | | Mixing Box. 1 to 2. | |
| | | | | | | | | | | | 1 to 2. | | 1 to 3. | | | | | | | | | | | | 1 to 1. | | 1 to 2. | | | |
| | No. 50 | No. 100 | No. 200 | Initial | Hard | 24h | 7d | 28d | 7d | 28d | 7d | 28d | 7d | 28d | No. 50 | No. 100 | No. 200 | Initial | Hard | 24h | 7d | 28d | 7d | 28d | 7d | 28d | 7d | 28d | | |
| 1893 . . . | 4 | — | — | — | — | — | 300 | — | — | — | — | — | — | — | 4 | — | — | — | — | 75 | 130 | — | — | — | — | — | — | — | | |
| 1894 . . . | 1 | 15 | 40 | 30 | — | 125 | 350 | 450 | 125 | — | — | — | — | — | 4 | 25 | 40 | 10 | 30 | 75 | 150 | 250 | 50 | — | — | — | 30 | — | | |
| 1895 . . . | 1 | 15 | 40 | 30 | — | 175 | 400 | 500 | 150 | 200 | 150 | — | — | — | 4 | 20 | 40 | 10 | 30 | 75 | 175 | 275 | — | — | 100 | 175 | 50 | 125 | | |
| 1896 . . . | 1 | 10 | 30 | 30 | — | 175 | 450 | 550 | 160 | 220 | 125 | 200 | — | — | 3 | 15 | 35 | 10 | 30 | 100 | 200 | 300 | — | — | 120 | 200 | 50 | 125 | | |
| 1897 . . . | 1 | 10 | 30 | 30 | — | 175 | 500 | 600 | 170 | 240 | — | — | 125 | 175 | 2 | 15 | 35 | 10 | 30 | 100 | 200 | 300 | — | — | 125 | 200 | 50 | 125 | | |

G. S. WEBSTER, *Chief Engineer.*

RICH'D L. HUMPHREY, *Inspector of Cement.*

as in this case, in excelling the foreign product both in quality and cheapness.

Mr. James Christie.—The statistics given by Mr. Lesley indicate what an important element of industry hydraulic cement has become. For some work it is indispensable, and for any purpose it is so much superior to lime mortar that it hardly pays to use the latter at all. The use of concrete for foundations of structures and machinery has become so universal that the occupation of the stone mason is much diminished. One of the many advantages of the use of cement concrete is that it can be so readily moulded into any desired form; an important saving in time can be effected over that required for laying of masonry.

Recently, I had a foundation for a large machine to put in. The exigencies of the case required the work to be completed in a single day, which was readily done; whereas, I am confident the same work laid in stone could not have been completed in the given time if all the masons that could have been crowded into the space had worked on it. When a light concrete is required a porous furnace slag can be used; or, on the contrary, if weight and great crushing strength is needed, trap rock makes the best body for the concrete. When a very strong and heavy concrete is desired, I have used a concrete of the ordinary composition, into which is incorporated iron cuttings from $\frac{1}{3}$ to $\frac{1}{2}$ by weight of the whole mass, and 1 pound of sal-ammoniac to each 50 pounds of iron. This concrete will weigh 210 to 220 pounds per cubic foot, and in one month will resist a crushing force of 3,000 pounds per square inch of surface, or about six times that of ordinary concrete.

*Stated Meeting, April 13, 1898.*

# THE REDUCTION WORKS FOR SILVER ORES AT ADUANA, SONORA, MEXICO.

BY MILTIADES TH. ARMAS,
Formerly Assistant Superintendent.

[*Concluded from p. 302.*]

*Sulphides.*—Twice a week all the accumulated sulphides are thrown upon a cloth filter in a vat with a false bottom, and dried. This sulphide is calcined in a reverberatory furnace at a very low temperature, and then incorporated in the cupellation with litharge.

$$AgS + 2PbO = Ag + 2Pb + SO_2.$$

The average grade of the sulphide for the fourth trimester of 1897 was:

| | Per cent. |
|---|---|
| Ag | 24·1 |
| S | 31·0 |

*Experiment.*—An experiment made to recover the sulphur from the sulphide, and which gave a promising result, was the following:

11·75 pounds of sulphide treated with lime and boiled with steam for an hour gave 54 liters of calcium polysulphide solution of 2° B. with 5·380 grams of sulphur per liter, and the residue was incorporated in the cupellation without any difficulty, any excess of lime in the remaining sulphide coming out of the cupel with the litharges.

Sulphur being dear in Mexico, a partial recovery of the sulphur and further experimenting to solve the problem in a way adaptable to the conditions of the country, is necessary.

*Cementation of the Copper in the Leaching Waters.*—For a long time these solutions were discarded. Experimental work, however, proved that the free iron, which is always

found in mattes of lead smelting, would easily precipitate the copper found in the solution as chloride or sulphate, besides the silver that it may contain. Furthermore, the mattes were to be exported, provided they contained a sufficient amount of copper to pay the expense of freight and duties, the real profit coming from the silver contained in them. It was decided, therefore, to enrich the mattes destined to exportation by allowing all the leaching waters to pass over them. The results were very satisfactory, I am glad to say, as mattes of 35 per cent. of copper could be enriched to 40 per cent.

*Concentration.*—Ores of a grade between 23 and 27 ounces per ton are treated by wet crushing in a 10-stamp battery, and the pulp passes through a 30-mesh screen.

Capacity of the 10-stamp mill: 19·8 tons per twenty-four hours; 17·0 gallons of water per minute.

The crushed ore passes to a hydrometric sizer, and thence to three rubber belt Frue vanners, each 6 feet in width. The one which receives the coarser stuff is corrugated, and its capacity is double the other.

The principal difficulty experienced in the concentration was the floating gray copper, which could not easily be recovered. Attempts of various kinds have been made, but with little success. The losses sustained thereby were as high as thirty per cent.

Adoption of more complex and perfect concentrating machinery could not be thought of, as the Company was not willing to undergo further expenses. To that must be added the scarcity of water, which, towards the approach of the rainy season becomes so great, as to cause the stoppage of concentration. Only local and inexpensive means to reduce the losses could be adopted.

We first changed the screen to No. 24, in order to reduce the extreme division of galena and gray copper. This reduced the losses by 30 per cent., mainly by the recovery of galena, but the loss in gray copper, owing to its cleavage, could not be avoided entirely.

Round-buddles were resorted to, but not with perfect success. However, I have reasons to believe that were it

not for other numerous occupations, and especially in the smelting department, which afforded me but little time, the round-buddle could give satisfactory results if tested thoroughly.

During the last six months of 1897 we treated: 2,389 tons of ore, containing 65,321 ounces concentrates; obtained 410,072 pounds, containing 48,768 ounces concentrates.

Cost per ton of ore treated:

| | |
|---|---|
| Labor in crushing | $0 30 |
| Crushing | 37 |
| Labor at the concentration | 51 |
| Store expenses | 24 |
| Machines, pumps, etc. | 10 |
| | $1 52 |

ANALYSIS OF THE CONCENTRATES.

| | Per Cent. |
|---|---|
| $SiO_2$ | 12· |
| Pb | 19·1 |
| Cu | 12·1 |
| S | 22·2 |
| Zn | 21·0 |
| $Al_2O_3$ | 1·2 |
| CaO | 0·9 |
| Sb | 3·2 |
| As | 4·1 |
| Fe | 2·9 |

*Agglomeration of the Concentrates.*—Agglomeration of the concentrates with slag from the lead smelter, while very liquid, proved a failure.

On the other hand, a preliminary roasting in a brick form was desirable, not only with a view of getting rid of some of its harmful elements, as S, As, and Sb, but also to give it solidity. To that effect experiments on various scales were made.

Agglomeration with clayish earth (a product of decomposition of rhyolite) of the following composition was made.

| | Per Cent. |
|---|---|
| $SiO_2$ | 54·0 |
| $Al_2O_3$ | 18·6 |
| $Fe_2O_3$ | 15·4 |
| CaO | 2·2 |
| $H_2O$ | 8·6 |

Fine charcoal coming from the screening of the fuel for the smelter was added in the proportion of 8–10 per cent., which rendered the brick porous and afforded economy of fuel. The quantity of clay which gave the best results in the agglomeration was 13 per cent.

| | Per Cent. |
|---|---|
| Clay | 13 |
| Charcoal | 8 |
| Concentrates | 79 |
| Size of the bricks | 8″ x 3″ x 1″ |

These bricks were made by Indians and dried in the sun. Very careful and slow roasting in stall gave the desired consistency and volatilization of some S, Sb and As, but the loss in silver was great.

ANALYSIS OF A BRICK OF CONCENTRATES.

| | Per Cent. |
|---|---|
| $SiO_2$ | 22·4 |
| Fe | 4·2 |
| $Al_2O_3$ | 4·0 |
| CaO | 4·0 |
| S | 11·4 |
| Pb | 16·6 |
| Cu | 8·6 |
| Zn | 20·6 |
| As | 2·1 |
| Sb | 2·4 |
| Ag | 0·52 |

*Smelting.*—All the ores of a grade superior to 130 ounces per ton, as well as the concentrates, are smelted in a water jacket furnace of the following dimensions:

| | |
|---|---|
| Diameter | 39″ |
| Capacity | 40 T |
| Number of tuyeres | 6 |
| Root blower | N° 4 |
| Blast pressure | 1½″ |
| Number of revolutions per minute | between 100 and 120 |
| Volume of air blown per revolution | 13 cubic feet |
| Diameter of blast pipe | 14″ |

The ores smelted were complex. The chief difficulty arises from the high percentage of Zn, As and Sb.

*Analysis.*—

IRON ORE.

| | | | |
|---|---|---|---|
| $SiO_2$ | 6·6 | $SiO_2$ | 23·2 |
| Fe | 57·0 | Fe | 41·0 |
| $Al_2O_3$ | 3·2 | CaO | 5·6 |
| CaO | 2·1 | | |

LIMESTONE.

| | |
|---|---|
| $SiO_2$ | 10·0 |
| $Al_2O_3$ | 0·8 |
| $Fe_2O_3$ | 3·4 |
| CaO | 47·0 |
| $CO_2$ | 37·0 |
| $H_2O$ | 1·8 |

I will not describe the details of smelting, because they are so well known, but only mention the difficulties with which we had to contend.

As we go deeper in the mine the ore is becoming more blendiferous. The concentrates also proved to be rich in zinc. No roasting of the ore could be done successfully as the losses in silver by volatilization were great, as is the case with rich ores.

For the zinc there was only one remedy in ordinary smelting, that of diluting it with a large amount of slag. Slag containing more than 8 per cent. of Zn did not give satisfactory results, but a large amount of slag, cost in fuel, time and iron, neither of which is cheap. On the other hand, as we had to contend with Indian unskilled workmanship, we were liable to be the victims of their carelessness, especially with ores containing such a large percentage of Zn and As.

The speiss formed ($As_4Fe$) is not readily fusible and not liquid when melted, forms hearth-accretions, and prevents a good separation of lead. To prevent this it is necessary to select a slag that requires a great heat for its formation, and fuel is dear in Aduana. Furthermore, any neglect on the part of the Indian at the tap-hole, for instance, by not keeping it in the proper level and nearer to the hottest part of the furnace, is liable to cause the speiss floating on the lead beneath the matte to chill. The scarcity of iron ore and

fuel, and the accidents mentioned above, compelled us to resort to matte smelting with as little flux as possible, trying, however, to obtain all the silver in the base bullion as long as the hearth was kept in good condition.

By operating in that manner we could get rid of the greater part of Zn and As. In a second operation, re-smelting the mattes, most of the lead and silver were recovered and the mattes themselves reconcentrated to about 40 per cent. of copper, which would pay very well to export.

In direct smelting, counting accidents and the large consumption of fuel (about 26 per cent.), to say nothing of the losses in silver by volatilization, the cost was greater than by smelting first for mattes and then re-smelting the same. Indeed, the latter required a lower temperature, was easier to smelt and did not cause important volatilization of silver. The consumption did not exceed 23 per cent. in both operations together.

In direct smelting, when it was attempted to extract the greater part of the silver, the matte could not be exported at a large profit. The figures below indicate the composition of mattes by the first and second methods of operation:

DIRECT SMELTING.

| Mattes. | A<br>Per Cent. | B<br>Per Cent. |
|---|---|---|
| Cu | 29·0 | 27·6 |
| Fe | 28·1 | 27·9 |
| Pb | 12·9 | 15·1 |
| S | 22·7 | 20·9 |
| Zn | 5·3 | 4·8 |
| Ag | 227·5 ounces per ton, | 169 ounces per ton. |

BY THE METHOD OF SMELTING FIRST FOR MATTE.

| | C<br>Per Cent. | D<br>Per Cent. |
|---|---|---|
| Cu | 42·8 | 41·9 |
| Fe | 21·0 | 20·4 |
| Pb | 9·2 | 10·1 |
| S | 22·1 | 23·4 |
| Zn | 2·0 | 1·9 |
| Ag | 97·5 ounces per ton, | 130 ounces per ton. |

TABLE OF LEAD BULLION.

| Number of Pile. | Weight in Mexican Pounds. | Ounces per 300 Pounds. | Ounces Contained. |
|---|---|---|---|
| 8–1 | 4,084 | 46 6 | 634 |
| 8–2 | 5,380 | 38·8 | 695 |
| 8–3 | 5,795 | 54·6 | 1,053 |
| 8–4 | 5,526 | 50·0 | 920 |
| 8–5 | 8,058 | 45·0 | 1,206 |
| 8–6 | 6,745 | 51 0 | 1,142 |
| 8–7 | 5,948 | 56·0 | 1,108 |
| 8–8 | 7,375 | 50·0 | 1,225 |
| 8–9 | 7,465 | 48·0 | 1,190 |
| 8–10 | 6,435 | 50·0 | 1,070 |
| 8–11 | 5,264 | 53·0 | 928 |
| 8–12 | 6,018 | 48·5 | 970 |
| 8–13 | 5,598 | 50·0 | 930 |
| 8–14 | 5,535 | 66·0 | 1,214 |
| 8–15 | 3,852 | 56·0 | 720 |
| 8–16 | 3,674 | 45·0 | 550 |

No automatic separation of slag and matte was made.

The slags did not carry more than 1·3 ounces per ton.

The charge was prepared in stalls, in thin alternating beds, so as to insure a more nearly perfect mixture of the ore and fluxes.

The charcoal was of mezquite wood and could stand well the crushing effect of the charge. Its price varied from $2.50 to $2.75 per 300 pounds.

Iron ore cost from $1.25 to $1.75 per cargo of 300 pounds.

*Cupellation.*—For the extraction of the silver from the base bullion and the sulphides from the lixiviation, no modern methods could be applied on account of the local conditions and because of the first expense, which the Company would not permit. Cupellation, however, is a very effective process, and the Mexicans ars quite experts in handling it. The loss in silver did not exceed 0·7 per cent. We used the English cupel. Dimensions: 46 x 59 inches.

The lining was made of a mixture of limestone and decomposed rhyolite, in the proportion of 100 of the former to 46 of the latter.

Its composition is as follows:

| | Decomposed Rhyolite. | Limestone. |
|---|---|---|
| $SiO_2$ | 51·0 | 10·0 |
| $Al_2O_3$ | 18·6 | 0·8 |
| $Fe_2O_3$ | 15·4 | 3·4 |
| $CaO$ | 2·2 | 47·0 |
| $H_2O$ | 8·1 | 1·8 |
| $CO_2$ | — | 37·0 |

Each cupel necessitates 1,579 pounds of the above mixture, which was moistened very slightly and passed through a No. 4 mesh screen.

The tamping is done by proceeding from the center in the form of a spiral. The circular indentations should overlap in part. At Aduana the tamping was done on a great number of layers.

The cupel, once in place, is heated very slowly so as to avoid cracking, and towards the end, that is, after forty-eight hours, heated intensely and varnished with litharge, when it is ready for charge.

The sulphides of silver are incorporated in the lead bath with twice as much litharge. The base metals and foreign matter of the base bullion are carried away by the litharge and the skimmings. Some of the copper, however, remains until the last moment, and only comes out with the last litharge, which is very rich, and, as a rule, is revivified and treated in the cupellation.

Two tuyeres furnish from a small ventilator the blast at a pressure of 7 ounces per square inch.

The capacity of a cupel is 3,500 pounds. The duration of a cupel is forty days, if managed carefully.

| | |
|---|---|
| Losses in silver | 0·7 per cent. |
| Consumption of wood per twenty-four hours | $7 50 |
| Labor, per twenty-four hours | 9 00 |
| Cost of cupellation per ounce is | 013 |

As the mint of Alamos accepted bars of silver with 985 fineness, we never tried to pass 992; the average, though, was 990.

Our monthly production in fine silver could be increased considerably, since the construction of two more reverberatory furnaces was effected.

Mr. Dorion conceived the idea of the utilization of the bed of the river, which is dry most of the time, as a filter for all the waters coming from the reduction works. A mile from the reduction works a well was dug, and the waters accumulated there. An electric pump pumped the water back, and thus the concentration could go on almost all the year without interruption. These two facts ought to increase the production considerably, if everything is managed skillfully.

During the year 1896 the cost of 1 ounce of fine silver can be stated as follows:

| | | Per Cent. |
|---|---|---|
| Cost in mining | $0 391 or | 36·0 |
| Cost in milling | 286 or | 26·4 |
| Cost in administrative expenses | 075 | 6·9 |
| Profit | 333 | 30·7 |
| | $1 085 | 100·0 |

# THE FRANKLIN INSTITUTE.

*Stated Meeting, September 21, 1898.*

## A NEW PROCESS OF COMBUSTION.

By Paul J. Schlicht,
Member of the Institute.

To the layman, combustion is a most perplexing and distressing problem. He seems to know by intuition that a large part of his coal-pile goes to waste up his furnace-chimney, and, while deploring the fact, is helpless against it. He has heard of the smoke-nuisance, and when he sees dense black clouds belching forth from countless chimneys he shakes his head and bemoans the terrible fuel losses. While his intuitive knowledge as to his house-furnace cannot be gainsaid by the expert, it is unfortunately defective when applied to that duskiness of the heavens produced by the thick carbon-laden breaths of factory-furnaces that defile the atmosphere of our manufacturing centres.

As a rule, the expert has given little thought or attention

to the stove and house-furnace, but he knows that those black out-breathings which to the layman are signs of such reckless waste are but of infinitesimal economic significance.

He can cite instances of evaporative performances that prove most satisfactory realizations of the calorific values of the fuels burned, and generally insists (at least such has been my experience) that in these well-designed plants substantial gains cannot be made by any improvements in combustion.

While this may be approximately true of some model plants where the most intelligent watchfulness and care are exercised and the fuel contains a high percentage of fixed carbon, it is not true when use is made of fuels whose com position is less favorable to the limitations of the ordinary process of combustion.

When the fuel contains too large a percentage of volatile matter the conversion of its energy into useful work ordinarily entails enormous losses. This is true more especially of those fuels that have hydrogen in excess of the quantity which will unite with their oxygen.

I am not aware that, in the industrial analyses of flue-gases, the losses due to the escape of combustible gases other than carbon-monoxide are taken into account. I know of instances of plants built in accordance with the best engineering practice where less than 40 per cent. efficiency has been realized in a clean boiler when such fuels have been used.

The stove and house-furnace and the industrial furnace are not in the same category.

In the former combustion is slow, in the latter generally rapid. Slow combustion in the stove and house-furnace is generally incomplete with the best fuels. Rapid combustion, except as to the volatile portions of fuels, is generally complete.

Incomplete and wasteful combustion in stoves and furnaces is due to insufficient and irregular air supply. In the industrial furnace an abundant air supply produces complete, even if in many instances, wasteful combustion with the best fuels and partially incomplete with others.

The fact that enormous losses occur in the burning of fuel in stoves and house-furnaces, and that in the best industrial plants the fuel energy is not adequately transformed into useful work, seems to me to offer abundant apology for my work in the field of combustion, which I will now endeavor to describe to you.

One of the objects of my process of combustion is to render available for useful work, in a simple manner, the greatest number of heat units in a given fuel, without material alteration of existing apparatus. It is especially with this phase of my invention that I desire mainly to occupy your attention.

The invention is based upon the fact, which I have discovered, that if a current of air is properly introduced into a chimney or flue through which hot products of combustion are escaping, the air current will flow in a direction contrary thereto, and, becoming heated in its contact therewith, will reach the sphere of combustion in a condition highly favorable to the union of its oxygen with all the combustible elements of the fuel.

In stoves, house-furnaces, and other slow-combustion apparatus, all of the air for combustion is supplied on the top of the bed of fuel. In industrial furnaces the desired rate of combustion determines the quantity of air to be admitted below the bed of fuel in addition to air supply on top.

In some instances the best results are obtained by closing, or nearly closing, the ash-pit door. In other instances, when a high rate of combustion is necessary, the resistance offered by the bed of fuel and the air pressure downward through the chimney or flue, so reduces the air pressure ordinarily exerted through the open ash-pit doors that no appreciably large air supply is furnished upward through the bed of fuel, but it is given a double air supply most favorable to high efficiencies.

In the ordinary process, combustion is most active over the grate bars, but its uniformity is constantly interfered with by the varying thickness of the bed of fuel and the gradual accumulation of ashes. In stoves and house-fur-

naces the losses from the escape of carbon-monoxide and other combustible gases up the chimney, in very large quantities, is the result of feeding the air for combustion upward under the grate bars, and through the bed of fuel. In industrial furnaces this upward draft generally results in the feeding of an excessive air supply, the losses due to which are known to those who have made a special study of the subject, and are now beginning to receive the attention they deserve by engineers generally. I will not refer to the breaking up of carbon-dioxide, about which much might be said.

The purpose of the house-furnace and heating stove is to maintain the temperature of rooms at a degree conducive to the comfort and health of their occupants. The purpose of the industrial furnace is generally to maintain a pressure of steam sufficient for power requirements.

An air supply adequate to thoroughly oxidize the combustible elements of the fuel would be inconsistent with the purpose of the heating stove and house-furnace, and would produce a great excess of heat, and require the burning up of a larger quantity of fuel than is now burned imperfectly to meet practical requirements. Moreover, to maintain fires it is necessary to shake down the ash daily so as to permit the air supply to reach the fuel. This produces, in mild weather, a temperature that is not conducive to the comfort or health of the occupants of rooms so heated.

By my process of combustion there is no solid and varying resistance to the air supply, as in the old process due to accumulations of ashes and varying thickness of fuel, but there is a constant supply of heated air that flows in contact with the combustion products, and which is regulated by the quantity of combustion products passing through the flue or chimney.

An evenness of temperature can at all times be maintained, labor is reduced, poisonous gases are converted into useful work, and the coal pile has been made often to last more than twice as long as ordinarily.

The feeding of air through the flue or chimney in regulated quantities on top of the bed of fuel in stoves and house-

furnaces by my process has secured some very remarkable results.

During mild weather the ashes have been allowed to accumulate for days, and a very small fire maintained on the surface thereof.

This has been done with a ten days' accumulation of ashes, an evenness of temperature and the burning of the fuel to clean ash with entire freedom from clinkers resulting therefrom.

In this process the combustion chamber is raised to a higher temperature than that attained in the ordinary process, and therefore when applied to hot-air furnaces previously incapable of furnishing warm air to all of the rooms of a house, the cold rooms have been successfully heated.

In addition to gains of from 25 per cent. to 50 per cent. in stoves and house-furnaces by the use of this invention, it has been found entirely practicable to use the smaller sizes of fuel, such as pea coal, instead of the more expensive furnace coal. As the calorific value of pea or any of the other sizes of small anthracite, when washed, is just as great as that of the larger sizes of coal, the burning of the former should give approximately as good results as the latter with my process, the saving in price of which should be added to the gain made by the burning of a smaller quantity of coal. Furthermore, the production of coal gas within and without the house is effectually prevented by this invention.

* * * * * * * * * *

I believe that the most common sources of waste in industrial furnaces when the fuel is high in fixed carbon, are those due to excessive air supply and to the non-transmission of a portion of the heat of the gases through the boiler plates, the rate of flow of the gases, being more rapid than the rate of transmission through such plates. I effectually prevent such wastes in plants favorable to the proper application of my invention, besides bringing back waste heat to the combustion chamber. When the fuel is high in volatile matter, the additional gains by my system are

very large. I have realized gains as high as 40 per cent. in well-designed plants burning such fuels.

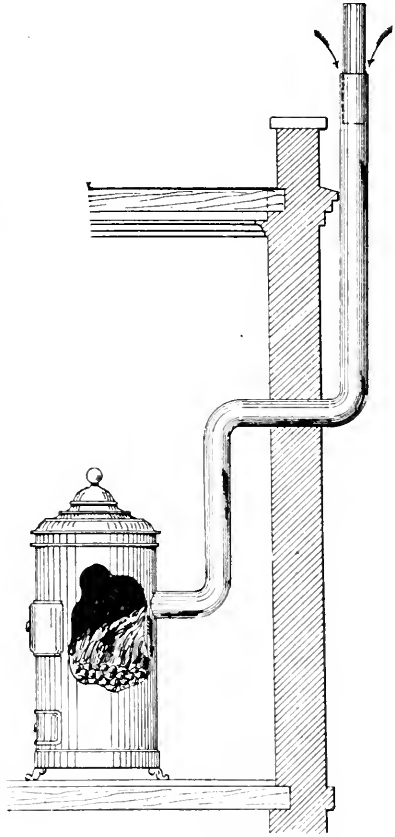
This latter gain was made at a plant where evaporative tests of two weeks' duration were confirmed by months of subsequent use of the system.

In industrial furnaces, where the draft has been insufficient to economically burn the smaller sizes of anthracite coals, I have realized large gains with my process in the burning of these cheaper fuels, burning them either alone or mixed with soft coal. I am well aware that with high chimneys and forced draft this can be done successfully, but I maintain that it can, in most cases, be done on a smaller investment and with a less deterioration of the boiler plant and greater economy by my system. Another great source of gain that has been realized with my process of combustion is the less frequent cleaning of boiler-furnace fires. At one large plant which had been run with the closest regard to economy, the services of two men were easily dispensed with.

Before describing my invention in detail, I desire to fortify myself by the testimony of others who have used my combustion process successfully, and who, when it was first presented to them, were skeptical, as you doubtless are, regarding the results I profess to be able to attain.*

The accompanying illustration shows a stove similar to the one with which I made experiments of different kinds to test the efficacy of my induced downward draft. I carefully sealed up every crack and joint with asbestos cement, so that the air supply could only come through the chimney. The length of the smoke pipe was about 25 feet, including the bend, and I was able to burn the coal so as to give an even heat many times longer than would be possible by the ordinary process. The coal was burned to an impalpable powder. It was a fairly good quality of anthracite coal, but burning it in the ordinary way produced clinkers. The appearance of the fire was different from that of ordinary

* Mr. Schlicht here read extracts from letters from users of his combustion process confirmatory of his claims to economy, evenness of temperature, etc.



fires, a peculiar pulsatory action being observable and a much greater heat produced by the small quantity of coal on the grate. The temperature of the escaping products of combustion was very low and there was no carbon-monoxide in the products. I proved to my own satisfaction with this stove that a very low rate of combustion could be maintained without the production of carbon-monoxide. Roughly the experiment indicated several times greater efficiency than shown with the old process.

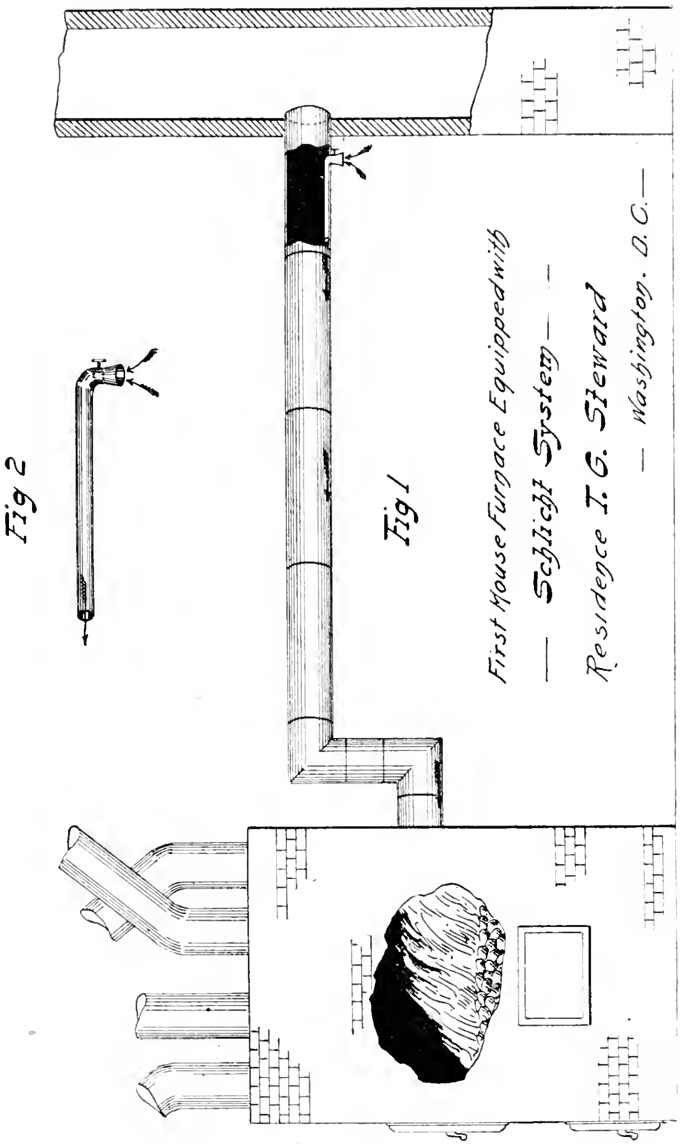
The annexed illustration shows the application of the Schlicht device to the furnace of Mr. Thomas G. Steward, now a member of the Board of Appeals of the United States Patent Office, but at the time of its application Chief Examiner of the Division of Stoves and Furnaces.

Mr. Steward experimented with my invention for months, not only to determine its value, but also to guide him in the allowance of my patent claims. He lived in a house which had the reputation of being a cold house, and which required the burning of a large amount of coal to render it habitable. Upon the application of my invention he was able to heat his house comfortably, and with a much smaller coal consumption than theretofore.

* * * *

When my application was first filed it was rejected on the ground of inoperativeness, the examiner denying that,

with the appliances shown, I could cause an air current to flow to the place of combustion. This fact I subsequently




proved by a practical demonstration in the basement of the Patent Office in the presence of the different examiners of

the division of stoves and furnaces. It was further verified by Mr. Steward's experiment with his own furnace. Since these early experiments, the appliances for furnaces have been greatly improved, but these early tests conclusively proved the correctness of the principle involved.

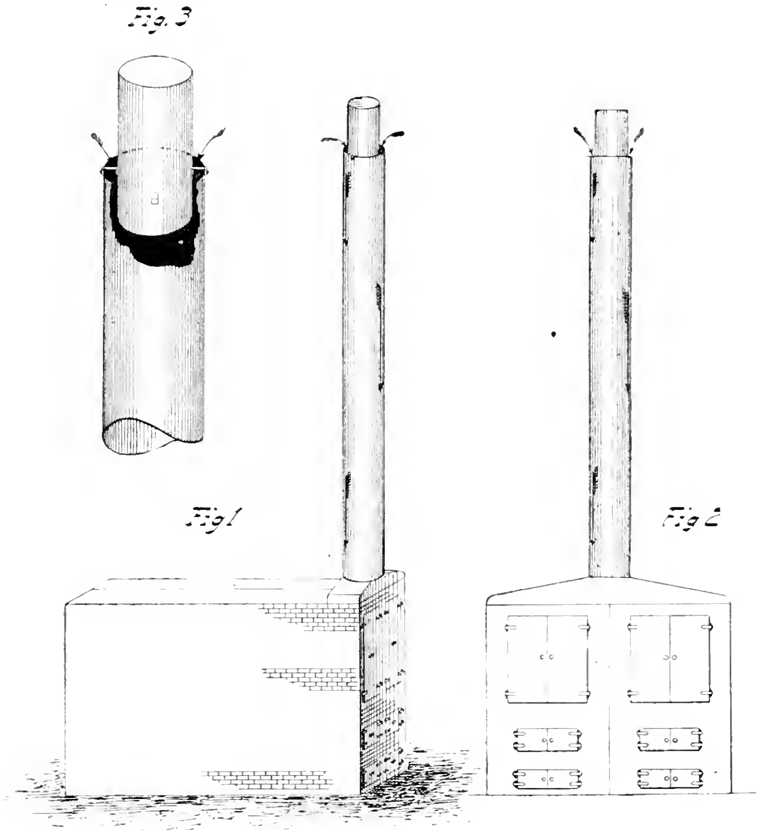
The air for combustion in industrial furnaces, as well as stoves and house-furnaces, as will be seen, may be admitted at the top of the chimney or through a flue leading to the same. The place for the admission of the air is determined by the conditions. In some instances they are such that the application to the chimney is the only feasible one, in others the application to the flue. The application to the top of the chimney secures contact with the current of escaping products of combustion throughout its entire length, giving the air abundant opportunity to be heated thereby.

One of the boiler-plants of the Barber Asphalt Paving Company (see accompanying illustration) typifies the conditions most favorable to the application of my invention at the top of the chimney of industrial boiler furnaces. Here the combustion products enter the chimney immediately after leaving the sphere of useful work, and its height and diameter are properly proportioned to the grate surface and to the quantity of coal burned per square foot of grate. If there were a separate chimney to each furnace, the results would be even more favorable, as the current of the combustion products from one boiler interferes somewhat with the current of combustion products from the other. If a less quantity of coal be burned per square foot of grate in one furnace than in the other, the quantity of air flowing into the combustion chamber will be proportionate to the combustion taking place therein. For example, if twice the amount of coal is being burned in one furnace than in the other, approximately twice the quantity of air will automatically flow to the combustion chamber of that furnace.

These two boilers are return tubular. For a part of the day the plant is run below and for the other portion, far beyond its rated capacity. It is while burning the largest

amount of coal per square foot of grate surface that the largest economy is effected. Evaporative tests with these boilers show the following results with "Sonman" bituminous coal:

| | Without Schlicht Process. | With Schlicht Process. |
|---|---|---|
| Pounds water from and at 212° per pound of coal | 10·79 | 12·96 and 12·68 |
| Horse-power developed | 166 | 188 and 172 |




Barber Asphalt Co.

PLAN "B"

A test made to determine the efficiency of process with reference to time required to melt 250,000 pounds of crude asphalt showed: without Schlicht process, 20 hours; with

Schlicht process, 17 hours, and requiring a consumption of $8\frac{3}{4}$ per cent. less coal.

The amount of work done at this plant was greatly in excess of that done in previous evaporative tests.

There are also Babcock & Wilcox's boilers at this plant, the equipment of which is at top of chimney.

The following illustration shows an early application of the Schlicht process to a steam plant. *Fig.* 2 shows the appliance in the chimney. It consists of a square tube rounded at its top, occupying about 70 per cent. of the area of the chimney at its lower part, and much less at the top. The restriction of smoke area at the top was made because I found the chimney larger than the normal, considered with reference to its grate surface, and believed that such reduction of smoke outlet would prevent the too rapid outflow of gases which might otherwise not adequately heat the air fed through the chimney. Bituminous coal was and is burned at this plant, and they were troubled with the smoke nuisance. Immediately upon the application of the Schlicht device the color of the smoke changed from dense black to a very light yellow, resembling wood smoke. * * *

Evaporative tests were made at this plant (a brewery), and showed variations with the rate of combustion. My compensation for the application of the process was determined by the lower cost for coal of each barrel of beer. From returns made by the brewing company, the cost of coal per barrel of beer up to June 1, 1898, for the previous year was $0.0695, while previous to installation of the invention the cost of coal per barrel of beer was $0.0855. This difference represents a saving of $0.016 per barrel of beer. In these calculations the price of coal was made the same for both years, although the market price was less for the last year.

About this time the German Patent Office, doubting the statement in my application for a patent that I could cause air to flow down a chimney in contact with products of combustion escaping therefrom, requested me to furnish affidavits of reliable experts in corroboration of this fact. Accompanied by Professor Greenleaf, formerly of Columbia Col-

lege, and John J. Powers, I secured evidence of this fact in a very simple manner. Pieces of tissue paper were strung upon a string with a piece of wood fastened at its lower end. The string was let down the chimney close to its side and

Fig 2

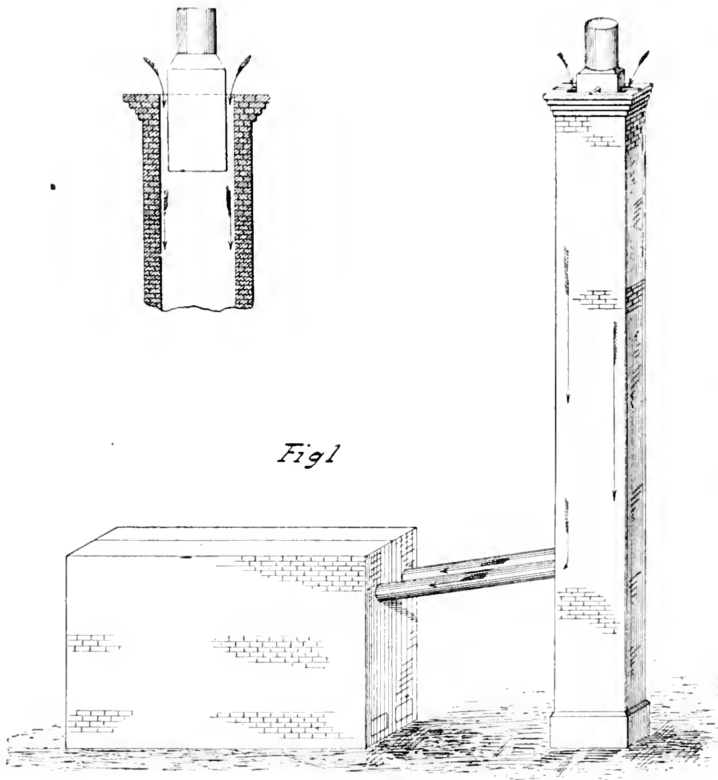


Fig 1

Eastern Brewing Co

PLAN "A"

the papers strung upon it were drawn down in the manner that pieces of paper on a kite string are carried to the kite, known to boys as "telegraphing to the kite."

This plant was run for long periods with ash-pit doors shut, during which period combustion was intense. The

remark was made by the stoker that, "the draft was very strong."

This illustration shows the application to the boiler plant of Fleischmann & Co.'s distillery at Blissville, Long Island. *Fig. 1* represents the entire plant with air-feed devices applied to the flue of each boiler. In a preliminary test on one boiler the heat generated with my process was greatly

Fig 2

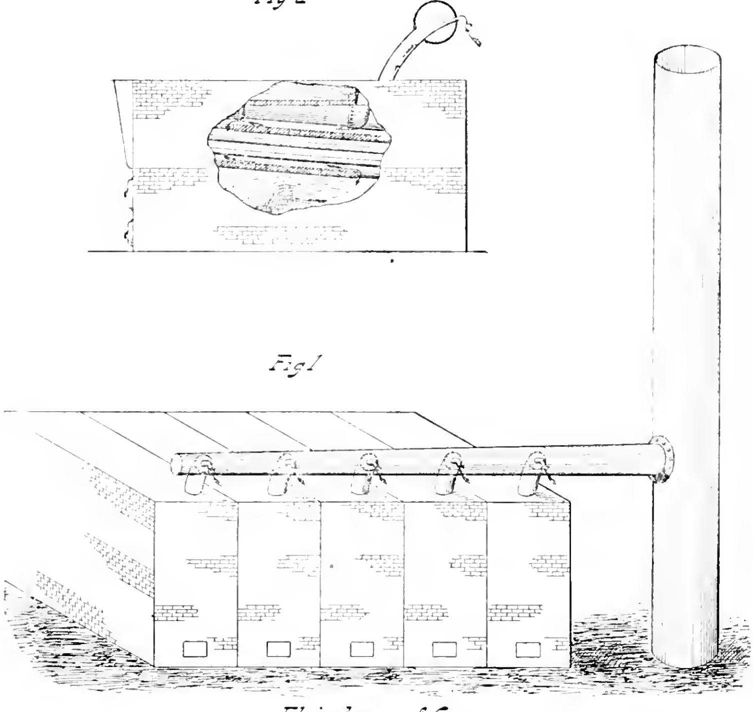


Fig 1

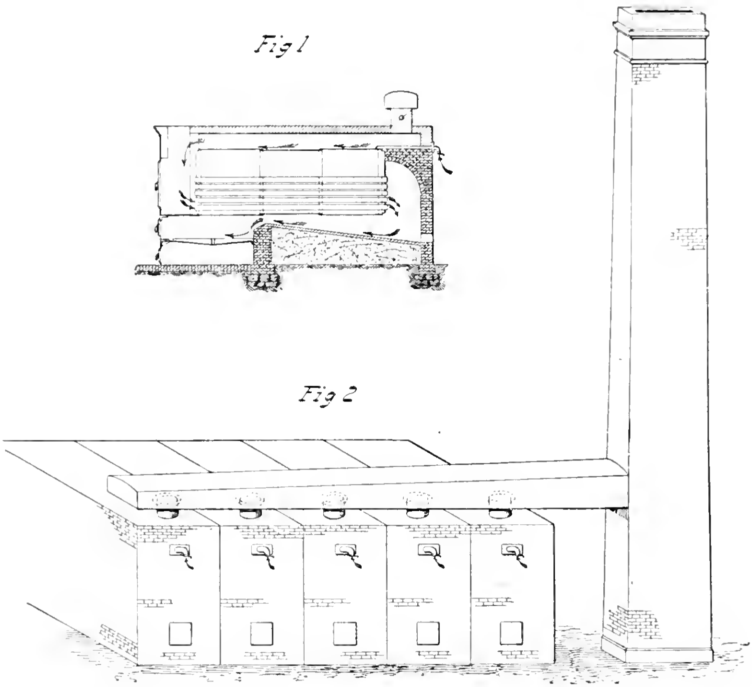
Fleischmann & Co.

Plan "E"

in excess of the absorptive capacity of the boiler and consequently the ratio of grate surface to heating surface was reduced, and 15 per cent. gain made. Before this was done the products of combustion were of a temperature sufficiently high to melt the pyrometer placed in the flue to determine temperature of flue-gases. In order to determine to what extent the reduction of grate surface was responsi-

ble for the gain made the air-feed pipe was shut off and a test was made the old way which showed a lower evaporation, proving that the reduction of grate surface, while beneficial with the Schlicht process applied to a Heine boiler, was decidedly disadvantageous without it.

Mr. Jacob Blumer, the chemist and superintendent of the Blissville plant of Fleischmann & Co., carried on a great



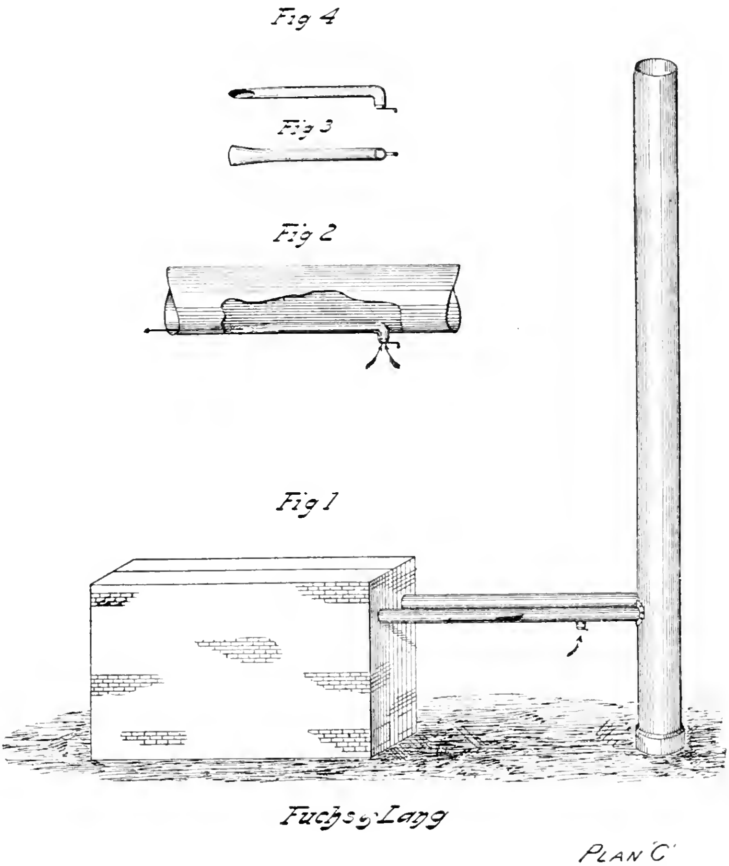

New York Quinine & Chemical Works
(Limited)

PLAN "D"

number of careful experiments to determine the cost of a horse-power with different fuels and different boilers, under the direction of Mr. Charles Schlagenhaufer, Superintendent of Manufacturing for Fleischmann & Co., an engineer of great sagacity and practical experience. I am permitted, on the authority of the latter, to state that independently of the gains shown by official evaporative tests there are so many other indisputable evidences of benefit that he cannot but

give the process his unqualified approval. Reduced coal bills, less ashes and refuse, greater uniformity of steam pressure, reduction of smoke, increased power when desired, are among these evidences.

Using "Coledale" bituminous coal an evaporative test showed: without the Schlicht system, an evaporation of




11·08 pounds of water per pound of coal from and at 212°. (The rate of combustion was 14 pounds per square foot of grate per hour.) With Schlicht process, evaporation was 12·19. Capacity test showed 8 per cent. better results than builders ever secured.

The illustration on page 370 shows the application to each boiler of the New York Quinine and Chemical Works, Limited. The air is introduced to each boiler as shown in *Fig. 1*.

Inferior coal was previously tried without success. Good results were produced with my process. Steadier steam pressure and greater boiler efficiency characterize boiler operations here. Very satisfactory economy is secured at this plant.

The illustration on page 371 shows application to flues leading from boilers of plant of Fuchs & Lang Manufacturing Company.

Tests were made with six parts of pea and dust, and one part of bituminous coal. The evaporation without process was 8·08 pounds of water; with process, 9·10. Evenness of steam pressure and high boiler efficiency characterized operations at this plant.

In consequence of lack of experience, difficulties with certain abnormally constructed plants were met with, but with the average boiler plants success has generally resulted from the application of the invention. To cite further details of successes and failures would tire you. To-day the commercial application of the process can be successfully made.

I beg to thank you for your courteous attention, and hope to be able in the near future to have something further to say that will interest you.

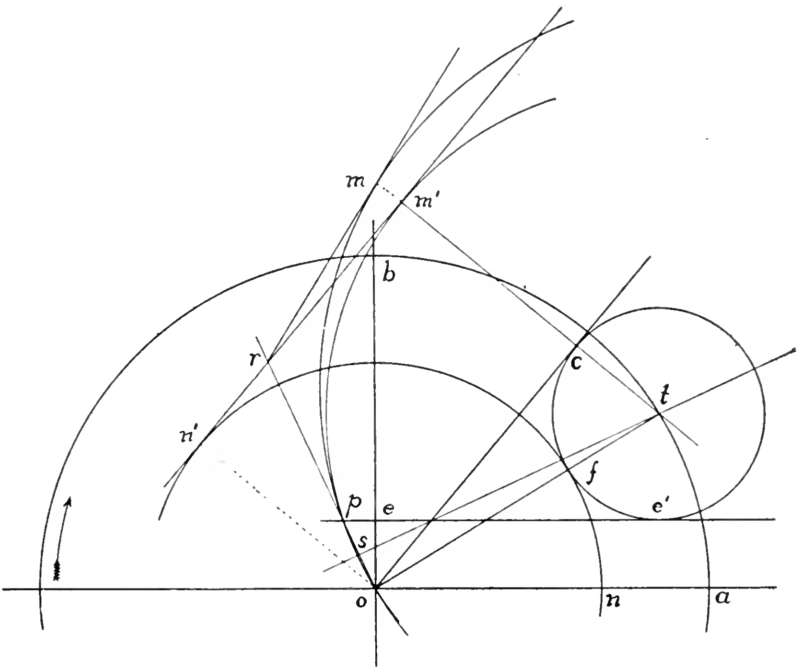
## BILGRAM'S DIAGRAM AND THE SOLUTION OF PROBLEMS INVOLVING LEAD.

By Merrill Van G. Smith.

Apropos of Professor Fox's recent article on the Zeuner Diagram, in which allusion is made to the approximate solution, by Bilgram's method, of one of the fundamental problems involving lead, the following is given to show that the same can be solved by a simple and exact construction.

The problem, which is that given as Problem IV in Professor Spangler's treatise on valve-gears and as Problem 15 in Professor Fox's article, is: Given the point of cut-off, lead and port-opening, to find the angular advance, lap and eccentricity.

Draw *o a* and *o b* at right angles, and lay off *o c* to represent the position of the crank at cut-off. Draw *e e′* parallel to *o a*, making *o e* equal to the lead. With *o* as a center, describe the arc *n n′* with the port-opening as a radius.




Draw *n′ m′* parallel to *o c* and tangent to arc *n n′*. From *o*, let fall *o p* perpendicular to *s t*, the bisector of the angle made by *o c* and *e e′*. With a center on *s t*, draw any secant circle, as *o p m*, passing through *o* and *p*. From *r*, the point where *o p*, prolonged, intersects *n′ m′*, draw *r m* tangent to this secant circle. Lay off the distance *r m′*, on *n′ m′*, equal to *r m*. Then, from *m′*, draw *m′ t* perpendicular to *n′ m′* and the point *t*, where this line intersects *s t*, will be the

center of a circle, which, with a radius equal to $c\ t$, will be tangent to $c\ e'$, $n\ n'$ and $o\ c$. And, joining the centers $o$ and $t$, of the circles $n\ f\ n'$ and $c\ f\ c'$, we have $t\ o\ a$ as the angle of advance, $t\ f$ as the lap and $o\ t$ as the eccentricity.

The proof the construction, in short, is:

The line $n'\ m'$, being parallel to $o\ c$, and tangent to the arc $n\ n'$, is distant from $o\ c$ an amount equal to $o\ n' = c\ m' = o\ f =$ the port-opening. The line $o\ p$, let fall from $o$ perpendicular to $s\ t$, the bisector of the angle made by $o\ c$ and $e\ e'$, is divided into equal parts, $o\ s$ and $s\ p$. Any circle having its center on $s\ t$, and passing through $o$, will pass through $p$. Circle $o\ p\ m$ is such a one; and, since $o\ r$ is a secant line, while $r\ m$ is a tangent, we have $\overline{r\ p} \times \overline{r\ o} = \overline{r\ m}^2$. But, $r\ m'$ is equal to $r\ m$; hence, $\overline{r\ p} \times \overline{r\ o} = \overline{r\ m}^2 = \overline{r\ m'}^2$. That is, a circle described through the points $o$, $p$ and $m'$, will be tangent to $r\ m'$, which is $n'\ m'$, at the point $m'$. Such a circle must have its center on $s\ t$, at the point where the perpendicular to the tangent at the point of tangency intersects $s\ t$. The point $t$ is the one thus found, and $o\ p\ m'$ is the auxiliary circle, which is here drawn only for purposes of proof. The line $m'\ t$, being perpendicular to $n'\ m'$, is perpendicular to $o\ c$; and the point $c$, where it intersects the latter, is one point of tangency of the circle sought to complete the diagram and solve our problem. A circle with its center at $t$, and a radius $c\ t$ will be tangent to $o\ c$ at $c$, and to $e\ e'$ at $e'$. It will also be tangent to the arc $n\ f\ n'$ at $f$. For, $t\ o = t\ m'$, being radii of the auxiliary circle $o\ p\ m'$, and $f\ o = o\ n' = c\ m'$; therefore, $t\ f = t\ c = t\ e'$.

This solution will, in the number of its lines and the nature of their description, be found quite as simple as, if not somewhat more so than, the solution to the same problem given by either Professor Spangler or Professor Fox by means of Zeuner's diagram.

ENGINEERING LABORATORY, UNIVERSITY
OF PENNSYLVANIA, July 2, 1898.

# CHEMICAL SECTION.

*Stated Meeting, September 20, 1898.*

## HIGH EXPLOSIVES AND SMOKELESS POWDERS AND THEIR APPLICATIONS IN WARFARE.

By Hudson Maxim.

The popular idea of an explosive is something which will burn up instantaneously without requiring air to support its combustion, and which may, therefore, be fired in a confined space.

It is hard to dissociate the idea of explosion from that of instantaneous reaction. Yet the differences in the time required for the consumption of various explosive bodies, although too insignificant for measurement by our senses, have a very great significance in their applications, especially as gunpowder.

Small fractions of a second become very important factors in controlling and directing explosive energy, especially in the attainment of high ballistics in guns.

Explosive compounds are burned in two ways: one, by combustion from surfaces exposed to a consuming flame; the other, by what is called detonation, by which the explosive is consumed nearly simultaneously throughout its mass by a wave action.

Combustion from surfaces requiring an appreciable time for the consumption of the explosive body adapts it to use as a gunpowder. The detonative form of explosion adapts a body to shattering or disruptive purposes, and unfits it as a gunpowder. The latter are termed high explosives. However, the function of an explosive, whether as a combustive or a detonative compound, is very largely determined by its physical character, temperature, and the conditions of confinement under which it is fired.

By making an explosive compound dense and hard, its susceptibility to detonative influences is lessened, owing to

the increased work imposed upon the reaction in overcoming the force of cohesion. Similarly, the adulteration of an explosive body with another and non-explosive body lessens its susceptibility to detonative influences, owing to the energy required in breaking up the foreign body.

It is well-known that guncotton can be ignited in considerable quantity and burned quietly away without detonation. If, however, a sufficiently large mass be fired, the localization of heat and pressure upon the surface of the burning body, owing to the energy required to displace the products of combustion as fast as set free, will cause the whole mass to detonate. In this instance the heat and pressure of the products of combustion upon the surface of the burning explosive perform the function of a detonator or exploder, like fulminate of mercury.

The reason why fulminate of mercury is so powerful a self-detonative body is owing not only to the weakness of the chemical bond between the molecules of its constituents, but owing as well to the high specific gravity and density of its products of combustion and their confining or tamping influence.

Nitroglycerin, in small quantities, may be burned like an oil, and even fulminate of mercury may be burned in a vacuum without detonation. Nitrogelatin, the most powerful commercial high explosive known, may even be used as gunpowder in small quantities and under light confinement.

Fibrous guncotton, which consists of an infinite number of small tubes, whose walls, although of a dense colloid, are very thin, owes the facility with which it can be detonated, to the fine state of division of this colloid.

If guncotton be dissolved in acetone, poured on a plate of glass and dried, the hard and hornlike product, as is well-known, resists detonative influences. However, if reduced to a fine powder its susceptibility to detonation is restored, or if re-dissolved in acetone, and poured into water in a fine stream, a fluffy, fibrous material is formed, resembling very closely the original fibrous guncotton, and which will detonate with equal ease and violence.

Cordite, the smokeless powder at present used in England, consists of 58 per cent. nitroglycerin, combined with 38 per cent. guncotton, and 4 per cent. mineral jelly, which ingredients, if simply mixed together, or mechanically combined by absorbing the nitroglycerin in the guncotton, would make a very high-grade dynamite. In fact, it would be one of the most violent high explosives known. But in the manufacture of cordite the guncotton is dissolved in a volatile solvent, such as acetone, which is afterwards evaporated out, the nitroglycerin being added to the guncotton while the same is in solution, the resulting compound forming, when dry, an elastic, rubber-like body.

The nitroglycerin in cordite is still, however, only mechanically combined with the guncotton, and the guncotton colloid holds the nitroglycerin in its pores in the form of minute particles or drops, similar to the manner in which water is held in the pores of a sponge, except the guncotton sponge is very much denser and of very much finer texture, the density and tenacity of the sponge serving as a sufficient barrier to detonation to permit of the use of the compound as gunpowder.

Cannon powder is not a powder at all. The term "powder" in this application is a misnomer. Explosive compounds employed as propelling agents for throwing projectiles from guns, instead of being in pulverulent form, consist, on the contrary, of large grains or pieces of solid material, varying from a quarter of an inch to more than an inch and a half in thickness, and sometimes, as in the case of cordite, big sticks of explosive material are employed eighteen inches or more in length.

Originally, however, gunpowder was actually made in the form of a powder, being a loose, mechanical mixture of sulphur, saltpeter and charcoal, and which, although it did not detonate in the gun, was still completely consumed before the projectile had moved its length; consequently, charges could not be employed large enough to impart high velocities to projectiles without giving excessive initial pressure.

It was found that, by compressing the explosive mixture

into dense and hard cakes, and then breaking them up into grains, more time was required for combustion by reason of the flame being to some extent localized or confined to the surfaces of the grains, so that, instead of being all set free at once, the evolution of the gases was made to consume sufficient time to permit of the projectile being displaced enough to give room behind it for the reception of the gases of the explosion before the complete consumption of the charge. However, with such powders the pressures fell off rapidly because of the diminished burning area of the grains as combustion progressed.

A powder is smokeless which leaves no ash when burned, but is converted entirely into gases. A little more than half the products of combustion of common black powder consists of solid matter or ash, and it is this solid matter which makes the smoke.

If guncotton be dissolved in a suitable solvent, like ace tone, and then dried, a very hard and hornlike substance is the result, which may be cut up into grains and used as gunpowder, but this substance is so hard and so dense that grains of it have to be made quite thin in order to secure its complete consumption in the gun, because it will not burn through a sufficient thickness before the projectile leaves the gun.

Owing to the fine granulation necessary to secure the complete consumption of a pure guncotton colloid, so much surface is presented per unit of weight as to preclude the use of sufficient charges to give requisite velocities without dangerous pressures. For this reason no pure guncotton powder, except in the form of the Maxim-Schupphaus multi-perforated grain, which will be explained further on, has yet been produced which has been successful in guns of more than four-inch caliber. Even in these guns, much higher ballistics are attained by multi-perforating the grains.

The addition of nitroglycerin to a guncotton colloid in its manufacture softens the material, and causes it to burn with greater rapidity, thus permitting of coarser granulation. However, in order to secure combustion through a

sufficient thickness of material to adapt it for use in guns of the largest caliber, nearly 60 per cent. of nitroglycerin is required. Such a compound is British cordite, and one too dangerously near being a detonative compound. Nevertheless, without multi-perforations there is no other method of securing the results.

Although a charge of powder in a gun is consumed with such rapidity as to appear to our senses to be instantaneous, still, it is far from being so. Although a grain of smokeless powder be consumed within one sixty-fifth of a second, still its combustion takes place entirely from the surface, and progresses with the most perfect regularity. Its combustion is similar to that of a piece of wood in the fire, only the combustion of the powder grain is infinitely more uniform.

When a rifle is placed to the shoulder and the trigger pulled, the time that elapses between the fall of the hammer and the flash at the muzzle is so brief that it appears to our senses to be perfectly instantaneous. Yet, during this time, the firing pin has moved forward and exploded the percussion cap, which, in turn, has fired the powder charge, and a certain period of time has been consumed in the combustion of the powder; the projectile has been started, at first slowly, and then forced along with accelerated velocity to the muzzle, and as the projectile moves away from the muzzle, the powder gases, rushing out at a much higher velocity than the projectile, impinge upon it, and are thrown outwards at right angles to the gun in the form of a disc, in exactly the same manner as though the projectile were held stationary in that position. Such, in spite of the evidence of our senses, is the relativity of velocities and time.

Probably no industry has, in its evolution, exacted more of the inventor than has the production of smokeless powder. Chemistry, physics, mechanics, mathematics and the science of gunnery, are all links in the chain upon which hangs success.

For about fifty years naval and military men have recognized the advantages of smokeless powder, providing such a compound could be practically produced. It was recog-

nized that the absence of smoke would give to the party using it a tremendous advantage over an enemy using black powder, owing to the difficulty that would be experienced in determining the direction or source of fire where smokeless powder should be employed; while, on the other hand, smoke-producing powder would not only cause the users of it to be readily located, but would, at the same time, serve to obscure their own vision.

Not until about 1888 had anything like a practical smokeless powder compound been produced. About that time, the French Government had, by a secret process, developed a smokeless powder for small arms, and which was used in the Lebel rifle, the substance being known as the Lebel powder. This compound is now known to have been simply a soluble variety of guncotton dissolved in a volatile solvent and then dried in thin films or sheets and cut up into small laminæ or squares.

The Lebel powder produced a great furore in Europe at the time, and the most wonderful claims were made for it. It was at that time that I began the investigation of the subject in England, returning soon afterwards to America, where I continued my work. A little later I engaged the services of Dr. Robert C. Schüpphaus, who was formerly connected with the American Xylonite Company. We joined our forces and our inventions, and have ever since been associated.

Up to that time, there had not been produced any smokeless powder for large guns, and even the then much-vaunted Lebel powder has since been replaced by another and superior compound.

The importance of solving the problem by the production of a successful smokeless cannon powder enlisted in the work many of the best chemists, mechanics and scientific men throughout the world, many of them being backed by limitless Government resources or by vast private capital.

Dr. Schüpphaus and myself entered the race for the production of a successful smokeless cannon powder with the field against us. Ours was a race against the world, and we were unfortunately handicapped by want of capital and the

difficulty of getting capitalists interested in a new and untried thing, and further handicapped by the dilatoriness, penuriousness and exacting methods of our own home Government.

In the face of all these difficulties and disadvantages, the Maxim-Schüpphaus smokeless cannon powder has been produced, and which has given the highest ballistic results ever known. All the most essential *desiderata* in a smokeless powder are its distinguishing features.

We discovered a new quality in nitro-cellulose, viz.: that by mixing a small percentage of soluble pyroxylin or gelatin guncotton with tri-nitro-cellulose, or high-grade guncotton, the mixture could be digested and rendered plastic, and could, under heat and pressure, be moulded into grains with very much less solvent, and that the grains so produced would shrink but little in drying, and would readily take and retain the shape of the forming die in all its geometrical details; whereas high-grade guncotton or tri-nitro-cellulose, if used alone, could not be moulded into similar grains without warping and cracking all to pieces in drying, while soluble guncotton is not only exceedingly difficult to work by itself, but presents to a great extent the difficulties encountered in the employment of tri-nitro-cellulose alone.

Our formula is an elastic one. We may either use no nitroglycerin at all, or may employ any percentage to meet the requirements of Ordnance Boards of different Governments; or we may replace nitroglycerin with an oxygen-bearing salt, such as nitrate of barium. But we prefer to employ, and recommend the use of, from 10 to 25 per cent. of nitroglycerin. A percentage so small has no disadvantages whatever, and has many advantages above a pure guncotton compound, or one containing an oxygen-bearing salt. Nitroglycerin is a compound that has been very widely misunderstood, and it is not generally known that pure nitroglycerin is even more stable, if anything, than pure guncotton, and that it will stand a higher heat test.

In the report of the Chief of Ordnance of the United States Army for 1896, page 197, after dwelling at length upon the advantages of progressive combustion, due to multi-

perforated grains, it is broadly stated that, "all things considered, the perforated cylinder in the Maxim-Schüpphaus powder appears to be the most suitable form for the colloidal smokeless powder."

It is obvious that a powder which presents a smaller initial burning area than another, and whose area increases, instead of diminishing, as combustion progresses, must be subject to enormously less variations in ballistics than a powder which presents the maximum area to the ignition flame and burns with a constantly diminishing area.

The Maxim-Schüpphaus smokeless powder, when compared with cordite, pound for pound, offers about one-fourth to one-fifth of the initial combustion area; and when compared with ballistite or cubical powders, it offers, pound for pound, less than one sixth of the initial combustion area. Therefore, when equal charges are fired, under like conditions, the Maxim-Schüpphaus powder will give at most, not more than between one fourth to one-fifth the variation in initial pressures that cordite gives. The same holds true for velocities, and the results of firing of our powder substantiate this claim.

One of the best and most comprehensive articles ever written on the Maxim-Schüpphaus smokeless powder appeared as an editorial in London *Engineering*, of August 20, 1897. The editor says:

"The distinguishing feature of the gunpowder invented by Mr. Hudson Maxim and Dr. Schüpphaus is its form. It has other characteristics of great value and originality, but these are only rendered possible by the peculiar shape in which the powder is moulded, and are, therefore, in a sense, subsidiary. . . . Whatever merit there may be in hyperbolic curves in a steam engine, there is none in a gun, for there the object aimed at is to impress the greatest possible amount of energy on the projectile with the least strain on the weapon. Evidently, this can best be done by a pressure sustained uniformly from breech to muzzle, such as would be represented by a rectangular diagram. The maximum pressure and the average pressure then become identical, and for any given ballistic result the maximum pressure is

greatly reduced below what it would be if there were sensible expansion of the gases in the bore.

"The result is sought to be attained in the Maxim-Schüpphaus powder, by giving to each grain such a configuration that the rate of burning shall keep pace with the motion of the projectile, and still maintain the space behind it filled with gases at a fairly constant pressure.

"If gunpowder grains be in the form of spheres or cubes, the rate of combustion is greatest at ignition, and gradually decreases as the grains diminish in size, while, on the other hand, the speed of the projectile through the bore rapidly increases. Hence, the pressure of the gases is not maintained. The ideal condition is that each grain shall, at the moment of ignition, present sufficient surface to combustion to give the required pressure, and that this surface shall rapidly increase so as to ensure more and more vigorous combustion."

The Maxim-Schüpphaus torpedo powder, that is to say, the grain I propose to employ for throwing high explosives from ordnance, is a cylinder six diameters long, and pierced longitudinally with nineteen angular perforations. The perforations are so shaped and so arranged with respect to one another, as to effect the complete consumption of the powder grain simultaneously with the intersection of the perforations with one another. In other words, when the perforations shall become so enlarged by interior combustion that they become tangent, the grain will be totally consumed.

The exterior of the grain is coated with a non-combustible substance, which, although consumed before the projectile leaves the gun, and also with the absence of smoke, still serves to confine the combustion nearly wholly within the perforations.

The torpedo powder grain, as already stated, will only present one-fifth the initial area to the flame of ignition that is presented by cordite, and about one-sixth of that presented by ballistite. Consequently, under like conditions of confinement, there will be only one-fifth the initial pressure for the same charge, and possible variations in velocities and pressures can be only one-fifth as great.

Now, therefore, if we employ a projectile of twice the weight and with the same area of base as that now employed with cordite, with a pressure of 35,000 pounds to the square inch, we shall still have less than half the pressure, and half the variations in pressures and velocities.

The key to a successful system of throwing high explosives from ordnance rests in the powder charge, or rather, upon the character of the powder grain. Second in import ance is the fuse; the third, the form of shell, and the fourth the high explosive to be thrown.

It is popularly supposed that the most essential requisite to a successful system of throwing high explosives from ordnance is to get them out of the gun gently—that high explosives of all kinds are very ticklish, and have to be handled with the utmost caution, and that the chief thing to be considered in the projection of high explosives from ordnance is the danger of their premature explosion in the gun, due to the shock of acceleration.

But this is not the case. In fact, nothing could be farther from the truth than such conclusions, for there are many high explosives as powerful as No. 1 dynamite, which may be handled and knocked about without any caution whatever, and which not only cannot be ignited when fire is applied to them, but which may be stirred up with a red-hot poker without any danger, or be fired into with shells from quick-firing guns without being exploded.

Such explosives may be thrown from ordnance at the same velocity with which ordinary shot and shell are now thrown from high power guns, and without the least danger from the shock of acceleration in the gun.

It is not generally known, but it is, nevertheless, a fact, that some of the most powerful of high explosives, such, for example, as wet guncotton, picric acid, known also under the names of lyddite, emmensite and melinite, are already successfully thrown from high power guns at service velocities.

A compound of picric acid and nitro-naphthalin, together with an admixture of nitrate of ammonia, is one such explosive compound. Picric acid, pure and simple, however, is

as powerful, volume for volume, as No. 1 dynamite, and it is, at the same time, wholly insensitive to any shock of acceleration to which it may be subjected in the gun.

Wet compressed guncotton may be fired from a gun at service velocities, and even exposed without any covering or protection whatever, to the white-hot gases of the propelling charge, a portion only of the wet guncotton being burned under the high heat of the powder gases.

An aerial torpedo filled with wet compressed guncotton would not be detonated by a quick-firing gun shell loaded with black gunpowder, penetrating it and exploding within the mass of wet guncotton.

Now, as it is the length of column of explosive in a shell which endangers it from the shock of setback or acceleration, we may increase the size of the projectile in cross-section indefinitely, to provide greater space for explosive without adding in the least to danger from shock in the gun.

In order to arrive at a correct understanding of what may be accomplished by this system of throwing high explosives from ordnance, let us take the present 12-inch seacoast rifle as a basis for our calculations. This gun weighs 52 tons, and throws a projectile weighing, loaded 1,000 pounds, at a maximum velocity of 2,250 feet per second on a pressure of 35,000 pounds to the square inch, with a powder charge of 250 pounds Maxim-Schüpphaus smokeless powder, grains 3 diameters long, and having seven perforations.

The bursting charge of the 12-inch projectile is only 37 pounds of black rifle powder.

Now in place of the above 12-inch sea-coast rifle throwing a 1,000-pound steel shell filled with only 37 pounds of black powder, a torpedo gun could be constructed which would have the same weight and which would cost the same, both for the gun and for mounting, as the 12-inch gun, but which would have a caliber of 24 inches, and which, with the same factor of safety that the 12-inch gun stands 35,000 pounds to the square inch would sustain a working pressure of 12,000 pounds at the breech and 10,000 pounds at the muzzle.

The torpedo gun would have practically the same outside dimensions as the 12-inch gun for the rear half of its length, the diameter being a little larger forward.

Now, suppose we consider both guns to be of equal length, and the length of travel of the shot the same, and let us estimate in the 12-inch gun the working pressure throughout its length to average 22,000 pounds from breech to muzzle, we have against this in the torpedo gun an average working pressure from breech to muzzle of 11,000 pounds, just one-half the average pressure of the 12-inch gun.

But the base of the projectile in the 24-inch gun is four times as great as that in the 12-inch gun. Consequently, we have a pressure of 11,000 pounds exerted through the same distance and over an area four times as great. Hence, the torpedo projectile is thrown from the gun with twice the muzzle energy as the 12-inch shell. This enables us to throw a projectile of twice the weight as the 12-inch shell, or weighing 1 ton, at the same velocity as the present 12-inch shell is thrown, and the additional $\frac{1}{2}$ ton of weight may be high explosive.

In other words, the torpedo projectile would consist of $\frac{1}{2}$ ton of steel and $\frac{1}{2}$ ton of high explosive, and we have, therefore, without any sacrifice of velocity, $\frac{1}{2}$ ton of steel and $\frac{1}{2}$ ton of explosive, in the place of 963 pounds of steel and 37 pounds of black rifle powder.

The high explosive which would be thrown would, pound for pound, be at least four times as powerful as black powder. This is a very low estimate. Consequently, the bursting charge thrown in the torpedo shell would be equal to more than 2 tons of black powder, and equal in force to the combined bursting charges of more than 100 12-inch shells.

[*To be concluded.*]

# CORRESPONDENCE.

## SCIENCE IN THE PUBLIC SCHOOLS.

Within less than a generation the scientific leaven has been working rapidly among educational authorities. The high school of to-day is equipped with apparatus and laboratories such as the best technical institution of thirty years ago did not possess. In our lower schools the maps are better than formerly, and a good modern geography gives information that ten years ago could not have been gathered except at a far greater cost. Of course, in this age, as in all its predecessors, a lazy or stupid pupil may go through school, and emerge therefrom with an amount of ignorance suggestive of the darkness of Egypt. A bright pupil, however, has advantages, such as no former era could have presented. Facts unknown to the investigators of our childhood, discoveries unmade until a recent period, observations of the latest date help a lad who has a scientific turn of mind to develop his faculties.

This improvement has been, in no small degree, brought about by the action of scientific institutions. Scientific investigation of some kind has always been in progress. In the English-speaking world it was quickened to a remarkable degree by the philosophers of Charles II's time, and the next century saw Franklin, Rittenhouse, Jefferson, and a host of other keen-witted Americans making experiments with almost boyish delight. Colleges and universities were for a long time ruled by an almost exclusively classical spirit, and scientific institutions grew up to give opportunities to men who wished to study hydraulics rather than Homer, and drainage in place of Demosthenes. For many years, such bodies were as far distant from the common school as from the classical academy. Public education was fought by many citizens and on many grounds; country trustees often favored the teacher who would accept the lowest salary; and the idea of giving even the barest kind of scientific training to the masses would have encountered a determined resistance. Men still under forty can remember how strong and persistent was the opposition to scientific teaching.

Year after year, the Franklin Institute and bodies of like character kept the even tenor of their way. Quietly and modestly, but steadily and effectively they did their work. Two generations ago intelligent men knew that there was a place in Philadelphia where one could obtain knowledge about meteorology, where scientific books unknown to the ordinary library might be found. Men who were fond of electricity, or who liked to know what was being done at the great iron works, or who wished to know something of the latest achievements in engineering could find congenial spirits at the Franklin Institute. As the wits and poets of old London flocked to the coffee-houses, so the men who liked to investigate and compare the results of their labors had what might be called their informal scientific clubs. Many a Philadelphian gained his knowledge of the growth of manufactures from the Franklin Institute exhibitions. Many a boy, sent to its drawing-school, grew interested in the long shelves of books very different from the dime novel, and in the apparatus which stimulated a desire to know more and more of the

achievements of human industry. To consult a dozen volumes of Patent-Office reports, or even to see half a hundred industrial publications is an experience to him who passes through it for the first time.

Every winter for many years the Franklin Institute has been scattering the seeds of applied science through the community. Few indeed are the subjects that have not been treated in some of its courses. Some of the papers read within its walls have dealt with matters so abstruse as to be beyond the grasp of all but the inner circle of specialists. Some have been of general interest. Quite a number have been within the comprehension of boys within their teens, and even small children have not been neglected. Writers for the technical press, and editors of the scientific columns in the dailies have been, directly or indirectly, indebted to this energetic, though unostentatious body for many facts and suggestions. It would be absurd to limit the influence of a university to a roll of its alumni, or the influence of a library to those on its list of membership. With equal justice it may be said that the Franklin Institute has been a mental force to many who have never connected themselves with it, or in any way acknowledged their obligations. Continuous effort tells, and the Institute's unbroken record of thorough-going scientific work is one of the proudest traditions of a proud old city.

Without any desire to withhold the meed of praise from any of the worthy institutions which, on both sides of the Atlantic, have held up the torch of science, we have spoken in particular of that body which so many manufacturers, engineers and inventors regard as their Alma Mater. It is not too much to claim that scientific bodies, of which the Institute is a type, have prepared the way for the text-books and apparatus of the modern public school.

ROLAND RINGWALT.

# NOTES AND COMMENTS.

## COMPARATIVE ECONOMY OF LOCOMOTIVE SERVICE ON ENGLISH AND AMERICAN RAILWAYS.

There has been an almost endless amount of controversy in the English and American engineering journals respecting the relative merits of the very distinct types of locomotive engines which characterize the railway practice of the two countries. The American engine is an evolution along mechanical lines dictated by the conditions of American service, which over a great portion of the United States are to-day even radically different from those prevailing in England and in Europe generally, and it is particularly significant that in the only country of Europe where the conditions approximate to those of America—namely, in Russia—the American type of locomotive is very generally in use.

On the score of performance as measured by fuel consumption, there it must be admitted that English locomotive practice is a long way ahead of the American. The inference might seem justified that this fact furnished conclusive evidence of the mechanical superiority of the British loco-

motive. As a matter of fact it is due to the laxity and general inefficiency of American methods of superintendence. Not that the needful knowledge and engineering skill is wanting among the Superintendents of Motive Power cf our leading railroads and their assistants, but rather because this great comparative inferiority in our locomotive practice is only just now getting to be generally known and admitted, and a reform which must involve a general change in the methods of the men in the locomotive cab—the engine drivers and their firemen—is difficult to inaugurate. It is there, however, that the source of the comparative inefficiency of American locomotive practice has been definitely located. The fault lies in the careless, inefficient and wasteful method of firing almost universally in vogue in the locomotive engines of the United States.

The English railway superintendents, a generation ago began investigating to find the cause of the wide variations in the coal consumption of their engines performing the same service. They found that economy of coal depended on the method of firing. The wasteful way was the easy one of dumping the coal into the furnace without regard to where it was needed; the economical way was to distribute it evenly over the grate, selecting the four corners and the sides in preference and covering the centre of the fire-beds somewhat thinner than the other parts. The English superintendents were quick to see the importance of having their engines properly fired, and by the general adoption of stringent rules to govern the engine drivers by making them responsible for the quality of the work of their firemen, and of the policy of giving premiums to the engine drivers whose engines showed the most economical coal consumption, the evil of wastefulness was speedily checked and much greater efficiency was obtained.

The editor of *Cassier's Magazine* has endeavored to ascertain approximately how great the saving of fuel has been on the English locomotives since the practice of hollow firing—as the reformed method is called—has become finally established. He quotes from Clark's great work on "Locomotive Engineering" first issued in 1860, wherein the rule is laid down that "the coal consumption of an ordinary passenger train might be reckoned at 14 pounds of coal per mile for the engine and tender, and 7 pounds per mile for each passenger coach." The average weight of a passenger train in those days may be taken as 100 tons, which with the above figures would mean a consumption of 49 pounds of coal per mile

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Writing in 1885, twenty-five years later, the same careful author revises his figures substantially. They make an instructive comparison with those given above, for the reason that the marked difference between them may be attributed in a large measure to the substantial reform inaugurated, during that interval, in the methods of firing the locomotives on the British railways. Thus: A typical English passenger train, the express between Manchester and Derby, weighing, engine, tender and coaches, 225 tons, was hauled at 50 miles per hour, with the expenditure of 28 pounds of coal per mile. On the Great Northern, a fast express hauled a 224 ton train (at a speed of 50 to 53 miles per hour) with 25¾ pounds of coal per hour. A London and North-western train hauled a gross load of 293 tons at 45 miles per hour, with 26½

pounds of coal to the mile. As compared with those of 1860, these figures represent an actual saving of one-half the coal consumption per train-mile—certainly an impressive lesson upon the importance of looking after the men who run the engines.

The value of this chapter from English railway history lies, as Captain Bunsby says, "in the application of it," and if it be applied to American practice, a discrepancy appears that is too great to be accounted for on any other supposition save that the great and crying evil on our railways is wastefulness of the grossest kind in the use of coal and in the firing of locomotives. Just how great this wastefulness is, and how urgent the need of a radical reform, will appear from the following quotation from *Cassier's* bearing on American practice: "Now, while the engines and trains described by Clark are running to-day, it is safe to say that no engine in the United States, doing similar work, approach them in economy of coal consumption. Indeed, there is positive knowledge of one well-known fast passenger train on one of the routes between New York and Chicago, with a gross weight not exceeding 275 long tons, where the coal consumption averages 75 pounds per mile. The fact, however, that such a comparatively large coal consumption excites no special comment, and that no extraordinary effort is made to reduce it, justifies the inference that it is not considered remarkable."

It is simply inconceivable that this striking difference between the economic performance of the English and American locomotive is due to mechanical superiority in design and construction in the former, for the American locomotive is sold all over the world in competition with those of English and European builders. Nor can it be accounted for by the general inferiority of American coals as compared with the Welsh stone coal, since, on the most liberal allowance, this should not affect comparative results by more than 10 or 15 per cent., while the difference to be bridged over is about 300 per cent. Perhaps, as *Cassier's* editor somewhat sarcastically remarks, "the unfortunate fireman who has to shovel in 75 pounds of coal to the mile has no time to do more than dump it in at the fire-box door."

Railroad engineering management in this country of late years has undergone a great change for the better, and especially in the case of the great trunk lines, will compare favorably with the best of other countries; but it is evident, from what has been said, that there is room for more intelligent supervision in this one important point. W.

## LIQUID HYDROGEN.

The advances that have lately been made in the improvement of the mechanical details of apparatus, have been so substantial that the liquefaction of air—until lately a most difficult and costly operation—has become so common that it has ceased to be a novelty. The English chemist, Dewar, in 1893, first drew attention to the subject by his remarkable experiments with the material at the Royal Institution in London. In these demonstrations he was enabled to produce only minute quantities of liquefied air with infinite difficulty, and at a cost which is said to have been at the rate of $2,500 for a quantity not exceeding a quart.

Since then, Linde, in Germany, and Tripler, in America, by improved compression apparatus, have shown that liquid air may be produced continuously and have supplied the product in large quantities, comparatively speaking, and at a cost of not exceeding, it is said, $1 per pound.

Tripler's work in this field has recently attracted much public interest, from the fact that he has supplied liquid air in quantities of from 5 to 10 gallons for lecture demonstrations before various learned societies.

One of these occasions was some months ago, at the Franklin Institute, where something like 8 gallons of liquid air were used, which had been shipped from New York in vessels resembling large milk cans with no other precautions than placing the vessel containing the liquid within another, the space between the two being lined with felt.

Hydrogen, however, has, until quite recently, apparently successfully defied all attempts to liquefy it. The claim has indeed been made by certain experimenters that a momentary mist within a glass tube indicated the incipient liquefaction of the gas, but these observations have been of so equivocal a nature that they have been accepted by scientific men with reservation.

At last, however, Professor Dewar has unquestionably accomplished this unique scientific feat, and has exhibited the liquid to Lord Rayleigh.

The successful experiment was made in the laboratory of the Royal Institution—the theatre of so many scientific triumphs at the hands of Humphrey Davy, Faraday and Tyndall—where Professor Dewar, according to the authority of the London *Times*, "actually produced the liquefied gas to the amount of half a wineglassful in five minutes by a process which would equally have produced a pailful had the requisite supply of pure hydrogen been forthcoming."

With no present or prospective practical usefulness attached to this achievement, it is not only of surpassing scientific interest, but also of great scientific importance, since it places at the service of investigators a means of commanding much lower temperatures—much greater cold—than it has hitherto been possible to attain, and scientific investigation has been compelled to stop far short of the limit of cold which liquid hydrogen can be made to yield.

In commenting on the properties of liquid hydrogen, the *Times* calls attention to the fact that the boiling point may be placed about 30° to 35° of absolute temperature; that is to say, about 240° below zero on the Centigrade scale. The following experiment is described to afford some conception of the degree of cold attained, viz.: If a tube closed at the lower end be immersed in the liquid hydrogen, it is almost instantly filled with solid air. The density of the liquid hydrogen is slightly more than half that of water.

One of the noteworthy things accomplished by Professor Dewar with this liquid, was the liquefaction of the rare gas helium which had hitherto resisted all attempts to effect its liquefaction. The boiling point of helium appears to lie very near to that of hydrogen itself.

The successful liquefaction of these two elements leaves nothing further to be done in this direction. There are no longer any known gases that remain in the category of incondensables, or permanent gases, as it was once the convenient mode of describing them.

It may be said in conclusion of the subject, that nothing now stands in the

way of the production of the liquid hydrogen in any desired quantity except the obstacle of its cost. This will always remain considerably higher than that of liquid air, because of the original cost of making hydrogen gas, but mainly because of the much greater difficulties attending its liquefaction. It will undoubtedly prove a valuable agent in the hands of physical and chemical investigators in the prosecution of researches that promise to add substantially to our knowledge of the ultimate constitution of matter. We can now reach down to within 30° of the absolute zero, where all matter is believed to be inert, dead. W.

## POWER FROM BLAST FURNACE GAS.

Engineers on both sides of the Atlantic continue to discuss with interest the possibilities arising from the utilization of the waste gases of the blast furnaces. From the results of experimental trials that have been made of the method, there would appear to be no longer any question as to the practical utility of turning to useful account a large amount of power that is now wasted. An instructive example of the present state of this interesting problem is afforded by the results gained in the practical operation of a blast furnace power gas plant at one of the largest steel works in Belgium. At these works, after a continuous operation of a year, the conclusion was found to be warranted that a gas engine with such trifling modifications as are required to adapt it to the nature of the gas, could be operated with the waste furnace gas without serious injury.

The details of this test, embracing all the conditions of the experiment, are very lucidly set forth by Professor Hubert, under whose direction they were made. Some of the more important of the results of his observations are taken from an abstract of them in *Engineering Magazine*.

He finds that for every ton of pig iron there are also produced about 5,750 kilograms of gas, equivalent to about 4,300 cubic meters. A blast furnace producing 100 tons of iron per day, therefore, will produce about 18,000 cubic meters of gas per hour. Of this quantity, about one-half will be used in the hot-blast stoves, leaving about 9,000 cubic meters available for power purposes. He estimates, from the results of his observations, that the utilization of this 9,000 cubic meters in the gas engine should realize 3,000 horse-power, as the value of the gas from a 100-ton furnace, which is from three to ten times the power hitherto produced by burning the gas under steam boilers. In actual practice, about 1,800 horse-power was realized, of which only 400 horse-power was required for the blowing engines, leaving 1,400 horse-power available for other uses, and which represents so much clear gain.

It is argued that with the progress now being made in the construction of large gas engines, it will soon be practicable to drive blowing engines with gas motive power cylinders, thus enabling the present expensive steam-power plant to be dispensed with, the gas engines replacing the steam engines.

An extremely interesting phase of the argument presented in favor of the innovation is best stated in the words of *Engineering Magazine*, as follows: "When, as is now frequently the case, the blast furnaces form part of a general iron and steel works, in which large quantities of power are required for

rolling mills, forges, machine shops, etc., the power produced by the gases in excess of the furnace requirements is directly available for the other mechanical operations, thus enabling such plants to compete, so far as power cost is concerned, with the great hydraulic power installations which depend on natural sources of energy.

"The matter seems to be passing well out of the hands of the investigators into those of the constructing engineers. It is now the turn of the engine builders to produce large gas engines, especially adapted for use with lean gas, and suited for continuous heavy duty, and the part of energetic iron masters to take active steps to introduce the new system. Already, it is reported, a blowing engine to be operated by gas power is being designed for the Cockerill Company, and others should not be slow to follow."

From all that has been said above, it seems safe to conclude that the difficult pioneer work involved in the careful study of the conditions of the problem has been accomplished with results which should prove of the highest importance. W.

## HOW SHOULD BOILER-HEATING SURFACES BE CALCULATED.

In a paper lately presented to the American Society of Mechanical Engineers, Mr. C. W. Baker questions the correctness of the usual practice of computing the horse-power of steam boilers from the heating surface. He affirms that by the method usually followed, there results an error of from 7 to 17 per cent., which, he says, is due to the practice of taking the surface in contact with the water, instead of that in contact with the fire gases, as the heating surface. Where these surfaces are flat, there will be no difference between one side and the other, but the boiler-heating surface is made up largely of tubes, and in these there is a difference of 17 per cent. between the interior and exterior surface in the case of a 1-inch tube, and of 7 per cent. in the case of a 4-inch tube.

The error to which Mr. Baker calls attention lies in the failure to appreciate the fact that the heating surface of the boiler, on which its steaming capacity depends, is the actual surface exposed to the fire or fire gases. With clean metal, the actual difference of temperature between the two sides of a boiler plate (or tube) is never more than 1° F., and Lord Kelvin has observed that for all practical purposes, we may consider that the heating surfaces of boilers conduct heat as though they were no thicker than paper.

It follows from the foregoing observations that the temperature of the heating surfaces of steam boilers is that of the wet side and not that of the fire side of the plate (or tube).

Although this fact is common knowledge among engineers, Mr. Baker claims that it has been generally overlooked by engineers and writers on engineering subjects, who have not insisted as they should that the fire side of boiler tubes should be that from which heating surface should be computed.

He illustrates his argument by the statement that if the fire side of the tubes be increased by forming ribs upon it—as is the case with the Serve tube—the steaming capacity of the boiler is thereby increased; but no such increase of steaming capacity will result from the placing of ribs on the wet side of the tubes.

Mr. Baker further makes the interesting statement that a thin coating of scale on the wet side of a boiler plate affects the steaming capacity less than a furring of soot on the fire side, which will be something of a surprise to most engineers. Another deduction of the author is that circulation of water in a steam boiler is of much less consequence than is generally supposed in its relation to efficiency. Good circulation is desirable because of its influence in assuring the equal heating of all parts of the structure, and hereby preventing undue strains in certain parts, but in Mr. Baker's judgment, it can have no effect on economy or efficiency.

The points made by the author seem to be well founded, and should receive the serious attention of steam engineers. W.

## BOOK NOTICES.

*Distribution de l'Energie par Courants Polyphasés.* Par J. Rodet, Ingenieur des Arts et Manufactures. Paris: Gauthier-Villars. 1898.

[Distribution of Energy by Polyphased Currents. By J. Rodet, Engineer of Arts and Manufactures. Paris: Gauthier-Villars. 1898. 8 vo., pp. 338, with illustrations. Price 8 francs.]

This work treats of all branches of the subject of polyphased currents with satisfactory thoroughness.

The several chapter heads embrace the following themes: History, treating of the general principles involved in the production of two-phase, three-phase and polyphase currents, and the principles of construction of motors for currents of these types; line construction and the consideration of the phenomena occurring in distribution; transformation of polyphase currents; motors; meters; and finally, the description of the notable installations for the transmission and distribution of electrical energy by polyphase currents.

W.

*Kosten der Krafterzeügüng.* Tabellen ueber die Kosten der effectiven Pferdekraftstunde für Leistungen von 4-1000 P. S., vei Verwendeung von Dampf, Gas, Kraftgas, oder Petroleum als Betriebskraft. Aufgestellt von Chr. Eberle, Lehrer an der Kgl, Maschinenbauschule zū Duisburg. Halle a. S.: Verlag von Wilhelm Knapp. 1898.

[*Power Costs.* Tables of cost per effective horse-power hour, for duties ranging from 4-1000 horse-power hour, with the use of steam, gas, producer gas or petroleum as the source of power. By Chr. Eberle, Instructor in the School of Machine Construction in Duisburg. Halle a. S. Wm. Knapp, 1898.]

This publication is a valuable compilation, made from German data, of the comparative costs of the several typical forms of power generators included in the class of heat engines, and cannot fail to prove extremely useful for reference by engineers. The tables embrace the performance of stationary steam engines with saturated and super-heated steam, locomotive engines, gas motors, producer-gas installations, and petroleum motors.

The tables are arranged to exhibit in order the costs of installation, yearly costs of operation, and costs per effective horse power hour. W.

*The Gas Engineer's Pocket-Book.* Comprising tables, notes and memoranda relating to the manufacture, distribution and use of coal gas, and the construction of gas works. By Henry O'Connor, Assoc. Mem. Inst. C.E., etc. New York: D. Van Nostrand Company. 1898. 8vo., pp. 438. Price, \$3.75.

The author has collected in this volume and arranged in practicable form for reference a great amount of information which the gas engineer will find admirably suited for his everyday use. The data and tables were collected by the author during a series of years for use in his practice as a gas engineer, and feeling, from his personal experience, the need of a work of this character, he has used the material as the basis for this pocket-book.

The examination of its contents, which we have been enabled to make, has given us a favorable impression of its comprehensiveness and thoroughness, and it can be recommended to the gas engineering fraternity as a valuable addition to the technical literature of gas manufacture. W.

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*Encyclopédie Scientifique des Aide-Mémoire.* Paris: Gauthier-Villars et Fils. Masson et Cie. 1898.

The following additional volumes of this capital series of technical handbooks have been issued since our last notice:

*Dariès* (*G.*), Conducteur au service des Eaux de Paris, etc. Calcul des Conduit d'Eaux.

*Laurent* (*H.*), Examinateur d'admission à l'Ecole Polytechnique, membre de l'Institut des Actuaires français. Théorie des opèrations financières.

*Aries* (*E* ), Chef de bataillon du Génie. Thermodynamique des systèmes homogènes.

*Minet* (*Adolphe*), Directeur du journal *l'Électrochimie.* Les Théories de l'Electrolyse.

*Minet* (*Adolphe*), Ingénieur, Directeur du journal *l'Électrochimie.* l'Electrométallurgie. Voie humide et voie sèche.

*Dufour* (*Albert*), Ingénieur civil. Etude d'un tracé de chemin de fer.

*Bourlet* (*C.*), Docteur ès Sciences, Professeur au Lycée Saint-Louis et à l'Ecole des Beaux-Arts, Membre du Comité technique du Touring-Club de France. Nouveau Traité des Bicycles et Bicyclettes. 2e edition. IIe Partie: Le Travail.

*Laurent* (*P.*), Ingénieur aux Usines Schneider et Cie. Polygone du Hoc. Déculassement des bouches à feu.

*Miron* (*François*), Licencié ès Sciences physiques, Ingénieur civil. Les Huiles minérales de pétrole, schiste, lignite.

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*Elements of the Mathematical Theory of Electricity and Magnetism.* By J. J. Thomson, M.A., F.R.S., etc. Cambridge: University Press. 1895. 8vo., pp. 510. Price, \$2.60.

The author has presented the fundamental principles of the mathematical theory of electricity and magnetism, and their more important applications in as simple a manner as the subject is capable of being treated. His work has already become well and favorably known to students, for whom it has been specially prepared. W.

*The Discharge of Electricity through Gases.* By J. J. Thomson, Professor in the University of Cambridge. (With diagrams.) New York: Charles Scribner's Sons. 1898. 8vo, pp. 203. Price, $1.

In this volume the author has collected the substance of four lectures on the discharge of electricity through gases, given at the University of Princeton, N. J., in October, 1896, in commemoration of the sesquicentennial of the University.

The subject is treated under three general heads, viz.: The consideration of the phenomena of the electrical discharges through gases in general, followed by the study of photo-electric effects, and the phenomena and effects of cathode rays. W.

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*Notes et Formules de l'Ingénieur*, du Constructeur-Mécanicien, du Metallurgiste et de l'Electricien. Par un Comité d'Ingénieurs, sous la direction du L. A. Barré et Ch. Vigreux, etc. IIe édition, revise, corrigée et considerablement augmentée, contenant près de 1,000 figures, suivée d'un vocabulaire technique en Français, Anglais, Allemand. Paris: E. Bernard et Cie. 1898. 8vo., pp. 1312.

The volume above named, one of the best and most favorably known reference books for engineers—civil, mechanical metallurgical and electrical—in the French language. It is more comprehensive, in fact, than anything of the kind of which we have knowledge in English. Its utility is fairly well indicated by the fact the present edition is the eleventh. It is capitally printed, illustrated, and indexed. The polyglot vocabulary at the end of the volume is a substantial addition to its value. W.

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*Jahrbuch der Elektrochemie.* Berichte über die Fortschritte des Jahres 1897. Unter Mitwirkung der Herrn Prof. Dr. Elbs, Giessen; Prof. Dr. F. W. Küster, Breslau; nur Dr. H. Danneel, Göttingen. Herausgegeben von Dr. W. Nernst und Dr. H. Borchers. IV Jahrgarg. Halle a. S. Verlag von Wm. Knapp. 1898.

The year-book of Nernst and Borchers has come to be recognized as the only authoritative collation of the progress of electro-chemistry from year to year. It fills an indispensable need for experts and students of this important and constantly growing branch of applied electricity. The present volume, though somewhat belated, will be found to have gained in thoroughness. W.

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*Lighting by Acetylene:* Generators, burners, and electric furnaces. By Wm. E. Gibbs, M.E. New York: D. Van Nostrand Co., 1898. 12mo., pp. 141. Price, $1.50.

The general interest in the application of acetylene for lighting will doubtless give to this work a wide circulation. The author diplomatically evades committing himself on the subject of the original invention of commercial acetylene. His descriptions of electric furnaces, acetylene generators, etc., will be found quite valuable by those interested in the general subject. A list of U. S. Patents, bearing on the subject, and the requirements of the New York Board of Fire Underwriters, which he publishes, add to the value of the book. W.

*Alkaloidal Estimation.* A bibliographical index of chemical research prepared from original chemical literature for the Committee on Revision. By Paul I. Murrill, under the direction of Albert B. Prescott. Published by the Committee on Revision. Ann Arbor, Mich. 1898.

This volume of fifty-eight pages octavo comprises a descriptive bibliographical index to the literature of the estimation of alkaloids, prepared from current scientific periodicals, by the Committee of Revision and Publication of the Pharmacopœia of the U. S. of America, 1890–1900. W.

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*Special Report on the Beet Sugar Industry in the United States.* Washington, D. C. Government Printing Office. 1898. 8vo., pp. 240.

The above-named volume contains the detailed report of the experts of the U. S. Department of Agriculture on the subject of the beet sugar industry, which has been greatly stimulated in recent years by the intelligently directed efforts of the Department. W.

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*Sugar Beet Seed.* A work for farmers, seedsmen and chemists, etc. By Lewis S Ware, M.E., etc. Profusely illustrated. New York: Orange Judd Company (Philadelphia Book Company). 1898. Price, $2.

The work above named contains the results of the author's extended study of the subject during many years which he has devoted to the beet sugar industry. The author's mission has been, and is, to promote the establishment of this industry on a successful commercial basis in the United States, and at considerable personal sacrifice of time and money he has maintained, for nearly twenty years, a journal—the *Sugar Beet*—devoted to the diffusion of knowledge on this important subject. At the present time, it appears as if he were approaching the realization of his aspirations. His thorough familiarity with every phase of the beet sugar industry—in which he is an acknowledged authority—renders any commendation of the present volumes a work of supererogation. W.

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*Methods for the Analysis of Ores, Pig Iron and Steel* in use at the laboratories of iron and steel works in the region about Pittsburgh, Pa. Together with an appendix containing various special methods of analysis of ores and furnace products Contributed by the chemists in charge, and edited by a Committee of the Chemical Section, Engineers' Society of Western Pennsylvania. Easton, Pa. Chemical Publishing Company. 1898. Price, cloth, $1; paper, 75 cents.

The methods described in this work represent the general practice which is followed in the principal iron and steel works in Pittsburgh and the region adjacent thereto. The committee named to edit the replies received in response to the circular issued by the Chemical Section of the Engineers' Society of Western Pennsylvania, was composed of Prof. F. C. Phillips, of the Western University of Pennsylvania; A. G. McKenna, Duquesne Steel Works, Dusquesne, Pa., and E. S. Johnson, of Park Bros. & Co., Pittsburgh. The methods of some sixteen iron and steel works are included in the volume. There is an appendix, giving analytical methods for certain special examinations occasionally of importance to the iron and steel chemist. W.

*Theory and Calculation of Cantilever Bridges.* By R. M. Wilcox, Ph.B., Instructor in Civil Engineering in Lehigh University. New York: D. Van Nostrand Company. 1898. 16mo., pp. 108. Price, 50 cents.

This volume replaces the original No. 25 of the Van Nostrand Science Series, on the "Theory and Calculation of Continuous Bridges," by Prof. Mansfield Merriman, published in 1875. It presents concisely the theory and methods of calculating the stresses in the trusses of cantilever bridges.

W.

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*The Tutorial Statics.* By Wm. Briggs, M.A., F.R.A.S., etc., and G. H. Bryan, Sc.D., F.R.S., etc. London: W. B. Clive. New York: Hinds & Noble, N.D. 8vo., pp. 360. Price, $1.50.

This addition to the publications of the University Correspondence College press, is distinguished by the same thoroughness which has gained for its companion volumes a wide popularity. W.

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# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, October 19, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, October 19, 1898.

MR. JOHN BIRKINBINE, President, in the chair.

Present, 116 members and visitors.

Additions to membership since last month, 9.

The principal paper of the evening was read by Mr. Edward H. Johnson, of New York, on the "Johnson-Lundell Surface-Contact System of Electric Railways."

In this system, the feeder wire runs in a conduit under the street and is connected to the car through buttons, or small steel nuts, which project about half an inch above the pavement, between the tracks. These buttons are not connected with the feeder wire except while the car is passing over them, and, therefore, cannot do any injury at any time to man or beast.

There are two lines, or rows, of these buttons, parallel with the rails. As the car comes along, two shoes, about 12 feet long, carried by the car just above the ground, press against these buttons. A magnet on the car, operated by a small storage battery, lifts a switch, which is under the street, which closes the circuit with the feeder wire, and the current passes through the buttons to the shoe, through the motor and back through the other shoe to the other side of the circuit. The magnet of the switch on the section just

beyond the car is energized just as the car reaches the section, and the section which the car is just leaving returns to its normal condition. In cases where there is, for any reason, a disconnection in the circuit, there is power enough in the battery to move the car over the break. The car is lighted from the battery circuit by low voltage lamps, and the battery is kept charged by the current from the feeder wire as it runs over the track.

This system is new and has been operated only experimentally on a line 3,000 feet long on Thirty-fourth Street, New York, where it has had eight months' service, said to have been satisfactory.

Further details are reserved for future publication.

Mr. Edward J. Moore presented a brief description of an improved form of marine boiler, of his invention. The apparatus is of the water-tube type, with two furnaces, and an economizer or feed-water heater, so disposed on top of the latter as to effectively utilize the heat of the ascending combustion products. The inventor makes the claim that his construction presents a much greater amount of heating surface for the same dimensions than is afforded in other boilers of this class, and specified numerous other advantageous features.

Prof. Joseph W. Richards, of Lehigh University, Bethlehem, by special invitation, gave an informal address, dealing with a number of items of scientific and technical interest which had come under his observation during a recent European visit. He referred, among other things, to the use of petroleum for fuel on Russian railways and steamboats; electric tramways in Germany, the sodium works at Oldbury, near Birmingham, England; the use of sheet aluminum in lithography in Germany, as a substitute for lithographic stone, and the recent pronounced development of the manufacture of aluminum in England.

Mr. James Christie, chairman *pro tem.*, expressed the thanks of the meeting to the speaker for his extremely interesting remarks.

Mr. Ernest M. White presented some remarks, with illustrations supplementing his communication at the stated meeting of September 21, on the subject of "Chimneys for Incandescent Gas Lamps."

Adjourned. WM. H. WAHL, *Secretary.*

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of the proceedings of the stated meeting held Wednesday, September 7, 1898.*]

PROF. L. F. RONDINELLA in the Chair.

The following report was adopted:

*Automatic Air-Brake Mechanism*—G. F. Jeffries, Reading, Pa.

ABSTRACT.—This invention consists of an arrangement whereby the brakes may be applied to a railway train from the roadbed, independent of the engine

driver. This is accomplished by a valve placed in front of the forward wheels of the locomotive. This valve has a long lever or handle located in such position as to come in contact with a trip, about 1½ inches above the rail, which can be placed in position by the brakeman, or raised and lowered by means of levers from a switch or signal, to prevent collisions caused by the oversight or neglect of the engine driver to observe the usual signals.

The Committee finds that while the device would perform its intended function, and commends the inventor for the conception of a life-and-property-saving invention, the benefits to be derived from its use are not sufficient to offset a number of detrimental and impracticable features it possesses. [*Sub-Committee.*—Jacob Y. McConnell, Chairman; C. H. Downs, Henry F. Colvin, Calvin G. Turner, Henry Harrison Suplee.]

*Smoke Nuisance Ordinance.*—An amended draft of this document was presented, and, after some discussion, was adopted and ordered to be transmitted to the Board of Managers.

The following report passed first reading:

*Pneumatic Dispatch Tube Apparatus.*—B. C. Batcheller, Philadelphia. Referred by the Institute.

A motion to reconsider the Committee's Report on the Heintz Steam Trap was adopted.

W.

## SECTIONS.

CHEMICAL SECTION.—Stated Meeting, October 18, 1898. President, Dr. Lee K. Frankel, in the chair.

Mr. Charles A. Hexamer read a paper on "Chemical Fire Extinguishers," which was freely discussed.

A communication from Mr. Wilfred Skaife, Montreal, Canada, on "The Field for Chemical Improvement in the Manufacture of Sugar," was read by title, and referred for publication.

An artificial stone, known under the name of "Reconstructed Granite," was exhibited and commented on by Dr. Wahl, Mr. Hexamer and Dr. Day.

W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, October 12, 1898, President A. E. Outerbridge, Jr., in the chair.

Mr. Wm. Griffith, Mining Engineer, Scranton, Pa., read a paper on "Anthracite Coal in Peru." Freely discussed and referred for publication. The thanks of the meeting were voted to the speaker. W.

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## Mining and Metallurgical Section.

*Stated Meeting, November 9, 1898.*

## THE MINING AND MINTING OF GOLD AND SILVER.

ABSTRACT OF AN ADDRESS BY ALEXANDER E. OUTERBRIDGE, JR.,
President of the Section.

The speaker said that as the increasing production of precious metals all over the world is attracting much attention, not only in the metallurgical world but from students of political economy, statesmen and others, he thought that a few reminiscences of his early experiences, commencing nearly thirty years ago and covering the period in which occurred the beginning of the greatest development of silver mining in this country, might prove interesting at the present time.

In 1869, the year in which the speaker entered the assay laboratory of the Mint as an assistant, the output of silver in the United States amounted in coining value to $12,000,000; in 1870 to $16,000,000; in 1871 to $23,000,000; in 1872 to $28,750,000.

In 1873, the year in which the "trade dollar" was created by Act of Congress, the production of silver amounted to $35,750,000.

In 1878, the year in which the Bland Bill was passed by Congress over the President's veto, the output of silver was reported by the Bureau of the Mint to have been $45,200,000. In 1892 the figures were $82,101,000. In the following year production declined to $77,576,000, and in 1897 the output was $69,637,172.

These official figures all refer to coining values and to calendar years. The commercial value of fine silver has fallen from $1.32 an ounce in 1869, to about 61½ cents an ounce at the present day. The commercial value of the silver product of 1897 was $32,316,000.

The production of gold has not kept pace with that of silver in this country, notwithstanding the considerable increase in the past few years. The output of gold from 1873 to 1896 inclusive, as determined by the Bureau of the Mint, was 42,751,613 fine ounces; the output of silver in the same period was 998,411,000 fine ounces.

High water-mark in the production of gold was reached as long ago as the year 1853, when the output was 3,144,374 fine ounces (value, $65,000,000). In 1869 the output was 2,394,563 fine ounces ($49,500,000) and, with one or two exceptions, each subsequent year showed decreasing production until 1883, when the minimum amount of 1,451,250 fine ounces ($30,000,000) was recorded. Each year since has shown an increase, and in 1897 the gold product of the United States was 2,774,935 fine ounces, of the value of $57,363,000.

The report of the Director of the Mint upon the production of the precious metals for the calendar year 1897, recently submitted to the Secretary of the Treasury, contains some impressive figures.

It is shown that the production of gold in the United States increased $4,275,000 in 1897 over that of 1896. South Africa made a gain of $13,854,192, Australasia a gain of $10,502,249, and Russia a gain of $1,709,970 in the same period of time.

In 1897, the value of the total gold product of the world is stated to have been $237,504,800, and that of the total silver $236,730,300 (coining value).

In 1887 the total production of gold is shown (in other official tables) to have been $105,774,900, or less than one-half that of 1897, and the total production of silver was $124,281,000, or a little over one-half that of 1897.

If we go back still farther to the decade 1811 to 1820, inclusive, we find that the total production of gold in the world during this period was but $76,063,000, or less than one-third of the production in the single year 1897, and the production of silver in any single year of that decade was less than one-tenth of the production in 1897. The production of gold in 1897 was almost exactly equal in value to the entire production of the world during the quarter of a century from 1811 to 1836!

The production of gold in the United States in 1897 was not the largest in the history of this country, as already stated, but it was the largest since 1854. In that year gold was produced to the value of over two and a half million dollars more than in 1897, while in the previous year, 1853, there was produced more than eight and a half million dollars in value of gold in excess of the output of 1897. The enormous production in 1853 and 1854 was due to the discoveries of placer gold in California. These were the banner years and production of gold in the United States gradually declined from that time until it reached the lowest ebb, in 1883, when it amounted to but $30,000,000 in value.

About fifteen years ago, improved methods of getting gold from low grade ores, and of refining base bullion and "doré" bullion (silver containing a small percentage of gold) began to be commercially developed, and in consequence thereof the production of gold has increased year by year. For these, and other reasons, it seems probable that the yearly production of gold in the future will show a gradual increase and will be less subject to fluctuations than it has been in the past.

While it is true that nuggets, grains and dust are still found by prospectors in newly-explored regions, most of the

gold is now obtained from widely distributed low grade ores by the aid of scientific processes. Notwithstanding the excitement over the Klondike discoveries, the output from that region is insignificant so far when compared to the total product of the country. Statistics show that the State of Colorado alone added twice as much gold to the world's stock in 1897 as did the Klondike region, and several other States largely exceeded the Klondike output.

The statement of the Director of the Mint that the gold product of the South African Republic exceeded that of the United States in 1897, is apparently creating much astonishment and comment just now, but the monthly returns (unofficial) from that region show that the output for ten months of the present year exceeded that of the entire year 1897, and it is estimated that South Africa's contribution in 1898 to the world's stock of gold will not be far short of $70,000,000!

American mining engineers who have been engaged in developing the South African gold fields have computed from surveys of the ground and numerous assays of samples of ore taken from different localities and at different depths that the gold contained in the ore in sight in the district known as the "Rand," or Witwaatersrand, amounts to the enormous value approximately of $4,000,000,000, and at the present rate of production it will take half a century to exhaust these deposits, even though no further discoveries be made. Australasia and the United States together produced more than one-half of the entire output of gold in 1897, and it is in these two countries that modern methods have been most largely adopted. Gold getting has been changed by modern scientific methods from a lottery to a comparatively safe even if more prosaic business, and for this reason, if for no other, the suitableness of this noble metal for use as a universal measure of value, is rendered even more apparent than in former years when the production was subject to greater fluctuations. The increase in production is keeping pace with increase in population, and the leading nations have long realized that while in former ages, beads, shells, skins, cattle, tobacco, farm products, tin, lead,

copper, and other metals have served useful ends as money; there is, in the present stage of development of civilization, but one material adapted to fulfil the function of a universal measure of value of all commodities, including labor, and this is the metal gold, which is, fortunately for mankind, so widely yet sparingly distributed that the increasing requirement for this purpose and increasing supply seem to regulate each other in a truly wonderful way.

Owing partly to the increasing magnitude of silver deposits at the Philadelphia Mint, commencing about 1871, and partly to a natural predilection for the analytical methods of the "humid assay" of silver, this work became the speaker's special occupation during the following ten years. Assays of silver increased from an average of about a dozen per day in 1870, to more than one hundred on many days in 1876, owing largely to the coining of "trade dollars," of which 35,965,924 in all were struck before this coinage was suspended.

After the passage of the Bland-Allison Act, in 1878, the silver deposits and assays increased to a still greater degree.

In 1881, the year in which the speaker resigned from the Mint to become the metallurgist of a private manufacturing establishment, the production of silver in the United States was nearly four times greater than in 1869, when he first entered the assay laboratory.

In 1873 Sir Norman Lockyer, the astronomer, and Professor Roberts-Austen, chemist of the Royal Mint, London, announced to the Royal Society that they had discovered a quantitative method of assay of gold and silver by means of the spectroscope, which they expected would supersede the chemical methods then in use, and the speaker was thereupon authorized by the chief assayer of the Mint in Philadelphia to make a thorough study for the assay department of the proposed method.

The assayer caused to be made alloys of gold and copper, gold and silver, and gold, silver and copper; these were carefully assayed, numbered, and delivered to the speaker, who took them to a private laboratory in the University of Pennsylvania, set apart for this experimental work, in which

there was placed for his use, by the courtesy of the professor of physics, a large spectroscope, a powerful Ruhmkorff coil and galvanic battery. Here the study of the spectra of the gold and silver alloys was carried on daily for over six months, a special instrument having been devised for holding the specimens, and constructed in the Mint by the late S. James, master mechanic.

A report was made in 1874 to the assayer, which was communicated by him to the American Philosophical Society, and published, with photo-relief reproductions of the original drawings, in their Proceedings (Vol. XIV, No. 93, *Trans. Am. Ph. Soc.*).

The Chief Assayer of the Mint, the late W. E. DuBois, in presenting this report to the American Philosophical Society, on May 16, 1874, gave the following introduction:

"It must have occurred to many, when the brilliant spectroscopic method of scientific research succeeded in detecting the presence of metals, in any given substance, even to an infinitesimal nicety, that the next step must be to determine the proportion of such presence; in other words, the qualitative must lead to the quantitative, as in other chemical processes.

"The Annual Report of the Royal Mint at London for 1872 (dated April 15, 1873) contains an official memorandum of Mr. W. Chandler Roberts (now Roberts-Austen), chemist of the Mint, from which it appears that he was engaged in examining this subject, at the suggestion of, and in connection with, the distinguished spectroscopist and astronomer, Mr. (now Sir) J. Norman Lockyer. No decided results had been reached; but Mr. Roberts concluded by expressing the belief that every effort should be made to render the instrument serviceable in the operations of minting. . . It seemed desirable that our own Mint should maintain its character for examining and adopting real improvements, and not wait indolently to hear what might be done abroad.

"One of the assistants in the Assay Department, Mr. Alex. E. Outerbridge, Jr., had, for several years, given special attention to spectroscopic studies, both in theory and

in practice, and to him therefore the subject was committed; with what propriety and what success will sufficiently appear from what he has written. This will be found in the two following communications to the Assayer.

"The details he has given are well worth careful study; but we cannot help noticing, in a few words, the astonishing paradox at which his experiments arrive; namely, that this method is, in one respect, by far too sensitive and minute; and in another respect far from being minute enough, to serve the uses of the assay. It was worth all his patient labor many times over to come to this conclusion, as we must come, in the present state of this branch of science. And it is likely that the natural and necessary imperfections of metallurgy, the want of complete atomic homogeneity in the mixing of metals, will forever prevent the spectroscope from taking the place of the present methods of assay.

"As Mr. Outerbridge has been careful to give facts rather than suppositions, he has omitted any explanation of the anomalous results in the final part of his report. And yet, it seems evident that where two metals are present, the spark will, to some extent, elect for its vehicle the one which is most readily vaporized. This is notably shown in alloys of gold with copper. It is also very striking in the alloy of nickel and copper, of which our 5-cent piece is made. The nickel, which constitutes one-fourth, controls the color of the alloy entirely; and yet, being far more difficult of fusion than the copper, scarcely shows a trace in this spectrum analysis. . . .

"These experiments, it is believed, will be of use to show what may, and what may not, be expected from the spectroscope in the way of analysis where several metals are components.

"They may also be of use in other departments of investigation."

The report showed conclusively that the novel method, though interesting from a scientific point of view, was not practical, owing partly to the almost infinitesimal amount of metal volatilized by the spark, which metallic vapor was

the subject of quantitative analysis by the spectroscope. The report was reprinted in the *Journal of the Franklin Institute*, the (London) *Quarterly Journal of Science* and other foreign journals, and its conclusions were, it is believed, accepted as final, and the chemical methods of assay still prevail.

The speaker said that an unexpected appointment, in 1876, as Resident Commissioner to the Centennial Exposition from one of the smaller colonies of Great Britain resulted in forming pleasant acquaintances and valuable connections with several other foreign commissioners representing important gold-producing regions of the world.

The exhibit of gold ores, nuggets and minerals from Australia was particularly fine. A notable feature was the display of fac-similes of the most famous gold nuggets that had been found in Australia. One of these, discovered in 1869, called the "Welcome Stranger," weighed 2,268½ ounces, and was sold for £10,000 sterling.

The fac-similes were made of plaster of Paris, heavily coated with gold leaf, and dusted with ferruginous clay in certain spots and cavities, and it was said that they resembled the originals so closely, that they could scarcely be distinguished from the genuine nuggets even by a critical eye.

On his way to Philadelphia, the Australian Commissioner stopped for several weeks in London, in order to exhibit the collection at the Crystal Palace, or some similar building. The night before the opening day he was at work until a late hour with his assistants, and the last case unpacked contained these fac-similes; they were placed in a glass showcase with the labels attached, stating the value of each original nugget, and each card had a small word (fac-simile) in one corner.

The next morning the Commissioner was astonished to find a guard of metropolitan policemen drawn up in front of the showcase, and he then learned that the night watchman, discovering all this wealth of gold, as he supposed, exposed in a glass case, not even locked, called the superintendent of the building, who sent post-haste for an emergency guard.

One of these gilded fac-similes was secured by the speaker at the close of the Centennial Exhibition and deposited in the cabinet of curios at the Mint, where it has often been mistaken for a large lump of virgin gold.

In 1876, a pioneer of the South African gold fields visited the Centennial Exhibition and brought with him a number of valuable nuggets, which he subsequently deposited in the Mint. He was an intelligent Scotchman, and he said to the speaker, "After the rich alluvial gold shall have been all taken by prospectors, like myself, others will come with machinery and secure far more gold from the refuse ore than the pioneers ever dreamed of." This prediction has come true. The Transvaal now leads the world in annual production of gold.

The cyanide process of recovering gold from low grade ores has been brought to great perfection in South Africa by American mining engineers, and the most recent publication by Ellsler states that nearly one-third of the gold of the Rand is now obtained by this process.

The speaker said that, in 1881, he read a paper before the Numismatic and Antiquarian Society descriptive of minting methods, and as these are practically the same to-day as at that time, this description will still suffice to show the delicate chemical and metallurgical processes, and intricate mechanical operations that are necessary to convert the precious metals into the coin of the Nation.

*Minting Methods.*—The precious metals are never found in the pure state, and they are deposited at the Mint alloyed with other metals, and in a great variety of forms, such as native grains, dust, amalgam, bars or pigs, old jewelry, etc. The mixed metals are known under the generic name of "bullion."

The bullion is first weighed in the "deposit weigh-room," where several balances are kept for the purpose; the largest of these will weigh as much as ten thousand ounces in one draught, and the scale will readily turn, even when loaded to its full capacity, with a weight of one hundredth part of one ounce. The metal is then placed in a box provided with a cover and lock and taken to the "deposit melting-room." Here it is put in a crucible which has been previously heated in the melting furnace and covered with a thin coating of borax, which forms a sort of fluid glass, acting as a cover to protect the metal, when it is molten, from the oxidizing influence of the air. A workman, wearing a pair of large canvas mitts (somewhat resembling boxing gloves) grasps, with a pair of iron tongs, a rod or stick made of plumbago, he

stirs the now fluid mass back and forth, up and down, round and round, for the purpose of rendering it thoroughly homogeneous ; the metal is then cast into an iron mould called a "shoe." It is plunged into water to cool, as well as to dissolve off any particles of the borax glass which may have adhered to its surface. It is now returned to the weigh room and reweighed.

A slight loss in weight usually occurs owing to a partial refining out of the base metals, and the new weight is the amount with which the depositor is credited.

Let us suppose that a depositor brings a miscellaneous assortment of old gold ; watch cases, jewelry, dentist's plates, etc., representing every grade of fineness or proportion of pure gold, desiring to obtain its equivalent in coin. We will follow in imagination the usual course pursued.

After the metal has been returned from the melting-room (where it was cast into the shoe mould) and the bar reweighed, a small chip is cut off from one end of the bar and taken to the assay laboratory.

*The Analysis.*—The sample is laminated or rolled into a thin ribbon and stamped with the number of the deposit which it represents ; it is then assayed to determine the proportion of gold, silver, and base metal, and so accurate are the processes of assay, that the exact value of a deposit, frequently aggregating many thousands of dollars in value, is determined to the fraction of a cent by calculations based on the assayer's report.

The largest weight which the assayer uses in making an analysis of gold bullion is the French half gram (or about seven and three-quarters grains troy).

The balances used in this work are marvels of mechanical construction ; they are so sensitive that a weight of one-twentieth of a milligram (less than one-thousandth part of a single grain) will cause the indicator needle to deflect a very appreciable distance from the zero point on the graduated scale marking the equilibrium. These little balances are inclosed in glass cases, provided with sliding windows to exclude any draught of air. The beam is usually made of aluminum, one of the lightest metals, and the knife edges rest on jewels. The weights are made of gold, silver and aluminum, and are graduated from the half gram, which is arbitrarily denominated "1,000," down to the ten thousandth degree.

The assayer first determines approximately the relative proportions of the metals existing in the alloy, and from this bases his more careful determinations ; he weighs out on the balance exactly one-half gram, or 1,000 parts of the alloy ; he wraps this in an envelope of pure lead and rolls it into the form of a "bullet." The bullet is then placed in a small "cupel" or cup, made of calcined bone dust, which has been brought to a white heat in the muffle or oven of the assay furnace.

The mass melts immediately, and the lead oxidizes rapidly by absorbing oxygen from the heated air which passes continually over its surface, and on account of the extreme fluidity of the oxide it sinks into the pores of the cupel, which absorbs it as readily as a sponge absorbs water ; the lead also carries with it all the base metals which may be originally combined in the alloy, but the precious metals not being oxidizable, simply melt, and are not so fluid as to be capable of sinking into the cupel. A separation thus takes place, and at the moment when all the base metal is removed, a beautiful

"flash" is observed to take place on the surface of the metal; the "button" of purified gold and silver resulting from this operation is then removed from the cupel, returned to the balance, and weighed; the loss indicates the proportion of base metal. Another weighing of the sample is then made, to which is added pure silver in the form of fine granules, in the proportion of about two parts of silver to one of gold, the alloy is enclosed in a sheet of lead and cupelled as before; the silver button remaining is laminated, coiled into a roll called a "cornet," and boiled in nitric acid. The acid dissolves the silver, leaving a little roll of nearly pure gold.* This gold cornet is then annealed in the furnace to give it toughness, and is finally weighed; this weight represents the proportion of pure gold. The proportion of silver is ascertained by subtracting the weight of the pure gold plus the weight of the base metal from the original weight of the assay sample.

Silver was formerly assayed in the same way, but it was long known that the result was not quite accurate, owing to a partial volatilization of the metal when exposed to the high temperature of the fire. Experiments were instituted by the French Government to overcome this difficulty, which resulted in the beautiful "humid process" devised by Gay-Lussac. This is one of the most accurate methods known to chemical science, and so complete was Gay-Lussac's original description that little room has been left for any improvements, and many thousands of dollars' worth of silver bullion are rapidly and accurately determined every day in the Mint in this way. The rationale of Gay-Lussac's method is very simple, viz.: a given amount of chlorine will precipitate a definite proportion of pure silver from its solution in nitric acid.

The assayer prepares two solutions of common salt water (chloride of sodium); one is known as the "normal solution," and the other as the "decimal solution" One begins and the other finishes the assay.

The sample of silver to be assayed is weighed out, as in the case of gold, the assayer taking care to place a sufficient weight of the alloy in the scale pan to contain at least one gram (a little over fifteen grains) of pure silver; the weighed sample is then placed in a glass bottle and a charge of nitric acid is added to it; the acid is caused to boil, and in a short time the silver alloy is completely dissolved.

A charge of the normal salt solution is then allowed to flow into the bottle from a glass "pipette," which is made of such a capacity that it shall contain just enough salt water to precipitate one gram of pure silver; the chlorine in the salt water combining instantly with the silver, precipitates it in the form of a white cloud; the bottle is agitated rapidly for a few moments, when the precipitate settles to the bottom, leaving a clear solution above; the assayer next allows a charge of the "decimal solution," which is one-tenth the strength of the normal solution, to flow into the bottle from a burette or glass tube with graduated divisions, each division marking one-hundredth the capacity of the large pipette. If any silver remains in the solution a cloud will be observed on the surface. Now, as this decimal charge is one-tenth the strength and one-hundredth the volume of the large pipette, it will, of course,

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*A faint trace of silver remains undissolved by the acid, called the "sur-charge." The amount is ascertained by proof assays, using gold 1,000 fine, and proper allowance is made for the sur-charge of silver.

precipitate just one-thousandth as much silver, or one milligram. The bottle is again agitated to settle the precipitate, and successive charges of the "decimal solution" are added until all the silver is precipitated, and then a simple rule-of-three sum gives the exact proportion of pure silver contained in the original weight of the alloy. The assayer guards against all probable sources of error by an elaborate system of checks, and each set of assays is accompanied in all its mutations by one or more "proofs" or synthetic assays, made either from pure metal or from alloys of known composition.

After the exact proportions of gold, silver and base metal constituting the alloy have been reported by the assayer to the superintendent, the value of the deposit is calculated, and the depositor is paid the full equivalent, less the charges for refining, the amount of charges depending, of course, upon the nature of the bullion.

*The Refining Process.*—The metal now passes into the hands of the "melter and refiner."

We will suppose that the representative deposit that we have already alluded to contains a small percentage of base metals, such as tin and lead, which tend to make the alloy brittle or "short," rendering it unfit for coin. The first operation to which it is subjected is intended to eliminate these impurities, and is called "toughening." The metal is melted in a crucible and an oxidizing flux (saltpeter) is added to it while fluid, the saltpeter or niter decomposes and liberates oxygen gas; the oxygen seizes the base metals forming oxides; these rise to the surface and are dissolved in the flux; the flux, when sufficiently thick, is skimmed off, and the purified metal, consisting only of gold and silver, is poured into cold water to form granulations. The next operation is designed to remove the silver; this is effected by boiling in nitric acid, when the silver dissolves, leaving the gold in a finely divided state.

The "plant" used for this purpose consists of a number of large porcelain jars capable of holding about 35 gallons each.*

These are arranged in a double row and heated by steam pipes; they are inclosed in a chamber provided with sliding doors to prevent the escape of the noxious fumes, which are carried into a tall chimney from which they issue in a yellowish cloud. The dissolved silver is drawn off by means of a large siphon made of native California gold (valued at $3,000) and transferred to a vat made of wood (capacity 2,000 gallons), resembling those used in breweries. The vat contains several hundred gallons of salt water, and the silver is precipitated by the chlorine, a workman facilitating the operation by agitating the liquid with a large paddle provided with a long handle.

The precipitated silver is drawn off into large filters placed on trucks and thoroughly washed by running water until the test of litmus paper shows that all trace of acid has been removed. The chloride of silver now resembles pure white cottage cheese. It is transferred to another vat lined with lead. Zinc (which has been previously granulated by pouring while melted into cold water) is added to the silver, together with a little sulphuric acid; the chlorine deserts the silver for the baser metal, forming a soluble salt of zinc. The so-

*The charge for each jar is usually 190 pounds of granulations and 175 pounds strong nitric acid

lution is allowed to flow off, and the precipitated silver, after having been thoroughly washed, is pressed into round cakes called "cheeses," dried in an oven and melted in the furnace ; it is finally cast into a bar, and is found to be uncontaminated with its former base associates, being usually 998 to 999 fine.

The gold which remained in the porcelain jars is in the form of fine powder, and resembles sifted gravel.

After thorough washing to remove the silver nitrate the gold sediment is placed in cast-iron pots and boiled in strong sulphuric acid with a little niter added ; it is then washed, dried, pressed into cakes and melted. The bars are nearly pure gold, about 999 fine.

All that now remains for the melter and refiner to do is to weigh out the requisite amount of copper to form the coin standard, which is 9 parts of gold or silver (as the case may be) and 1 part base metal. In other words, our coin standard is nine-tenths fine.

The alloy is melted in large crucibles made of plumbago, holding over 6,000 ounces, and constantly stirred to render the mass homogeneous. The standard metal is cast into flat bars called ingots, 12 inches long, ½ inch thick, and from ¾ to 1½ inches wide ; the ingots are filed to remove the ragged edges, and the rough tops cut off with large steam shears. Two samples from each melt are assayed, and if the ingots are found to be of the proper fineness and of uniform composition, they are delivered to the coiner.

*The Mechanical Processes.*—The coiner transfers the ingots to the rolling mill, and when they have been sufficiently laminated by successive rolling and annealing, the strips are passed through a machine called the "draw bench," for the purpose of reducing them to the exact thickness required for the coin. This operation is similar in principle to wire drawing, and consists simply in squeezing the flat strips of metal between two stationary steel cylinders set to the desired gauge. The strips are now passed to the cutting press, which consists essentially of a round punch, the size of the "planchet," or blank required for the coin, working up and down very rapidly into a hole on the steel bed plate.

The strips are passed by hand through the press, and the blanks fall into a box below. The unused portion of the strips or "clippings," is returned to the melter and refiner and remelted. The planchets are next taken to the "adjusting room," where may be seen a number of ladies seated at a long table, each one provided with a little balance and a file. Each lady is supplied with a pile of planchets, and she proceeds very deftly to weigh each one against a properly adjusted counter-weight. The planchets that are too light are thrown into a separate pile and returned to the melter and refiner, to be remelted with the clippings, while those that are too heavy are adjusted by filing on the edge. Some years ago a novel automatic adjusting machine, designed by Mr. Ludwig Seyss, of Vienna, was introduced for the purpose of facilitating the work and diminishing the necessity of hand labor. It is an exceedingly beautiful and ingenious piece of mechanism, but is too complicated to admit of an intelligible description without the aid of sectional drawings. A description of this instrument will be found in the *Journal of the Franklin Institute*, of February, 1878. It not only weighs the blanks automatically, but also separates them into three kinds ; those that are too heavy falling into one box, the light ones into another, and those of the right weight

into a third. The machine will weigh and assort as many pieces in an hour as five expert ladies can by hand, but when we consider that there are ten balances in the machine, engaged in weighing at the same time, and only five used by the ladies, they must be awarded the palm for expedition.

The machine also requires the constant attention of one person to supply the blanks or planchets, and frequent attention of the expert adjuster of balances. When the additional cost of steam power and wear and tear of the parts is added to the original cost of the apparatus, its merit from an economical point of view is not so great as would at first sight appear.

The next operation to which the blank pieces are subjected is to impart the raised edge, technically called "milling."

The machine used for this purpose is an American invention, and is admirable for its simplicity as well as for the rapidity with which it accomplishes the work.

The blanks are fed by an attendant into a tube, and they are drawn horizontally, in single file, through a gradually narrowing channel formed by a groove in the periphery of a rapidly revolving disk on one side, and a stationary segment of corresponding curve on the other, keyed a little closer to the wheel at one end. The blanks are in this way compressed on the rim, acquiring the "milled edge." This machine is capable of milling as many as 1,200 pieces per minute.

The blanks are now taken to the pickling vats, where they are immersed for a couple of minutes in weak sulphuric acid for the purpose of removing the black oxide of copper; they are then washed in pure water and placed in a rotating cage filled with sawdust. This rapidly dries the blanks, and when removed to the coining room they have acquired a fine surface.

*The Coining.*—The early methods of coining were exceedingly crude and imperfect. The metal was hammered into a thin plate; pieces of irregular size were cut out and beaten into a bullet shape; this bullet was placed on a sort of anvil having the reverse die cut upon its face.

The obverse die was held in the hand like a punch, and by the aid of a heavy hammer the bullet was flattened out and coined at the same time.

There are many interesting specimens of this antique coinage to be seen in the Mint cabinet. The oldest are to be found in the case devoted to coins of the Greek Republic, dating back to seven centuries before the Christian era. It was not until the middle of the sixteenth century that the forge and hammer were succeeded by more scientific methods.

Formerly coins were struck in presses worked by a screw; but we adopted, many years ago, the admirable invention of a Frenchman, named Thenollièr, which has been further improved upon by the skill of a former coiner, the late Mr. Franklin Peale. This machine operates on the mechanical principle of the "toggle joint" (of which the elbow-joint is a familiar example). It is controlled by a lady who feeds it with the blanks, which she places in a vertical tube. A pair of "feeders" catch the bottom piece and carry it forward, where it rests in the "collar" between the upper and lower dies; the lever is now descending with the upper die while the lower die remains fixed; the pressure increases with perfect uniformity up to the maximum, which is equivalent to about 10 tons for the dime, 80 tons for the double eagle and 120 tons for the silver dollar. The pressure gradually decreases again by reason

of the relaxation of the upper joint, the lower die pushes the piece out of the collar into which it has expanded, and from which it acquires the "reeded edge." Meanwhile, the feeders have provided another blank, and as they bring it forward they push the coined piece into a channel, through which it slides into a box beneath the machine. The coins are then inspected by the foreman, and any cracked or defective pieces set aside.

The larger denominations of coin are counted by hand, and the smaller pieces, as well as the "bronze" and "nickels," are numbered by means of a simple and ingenious arrangement called the counting board

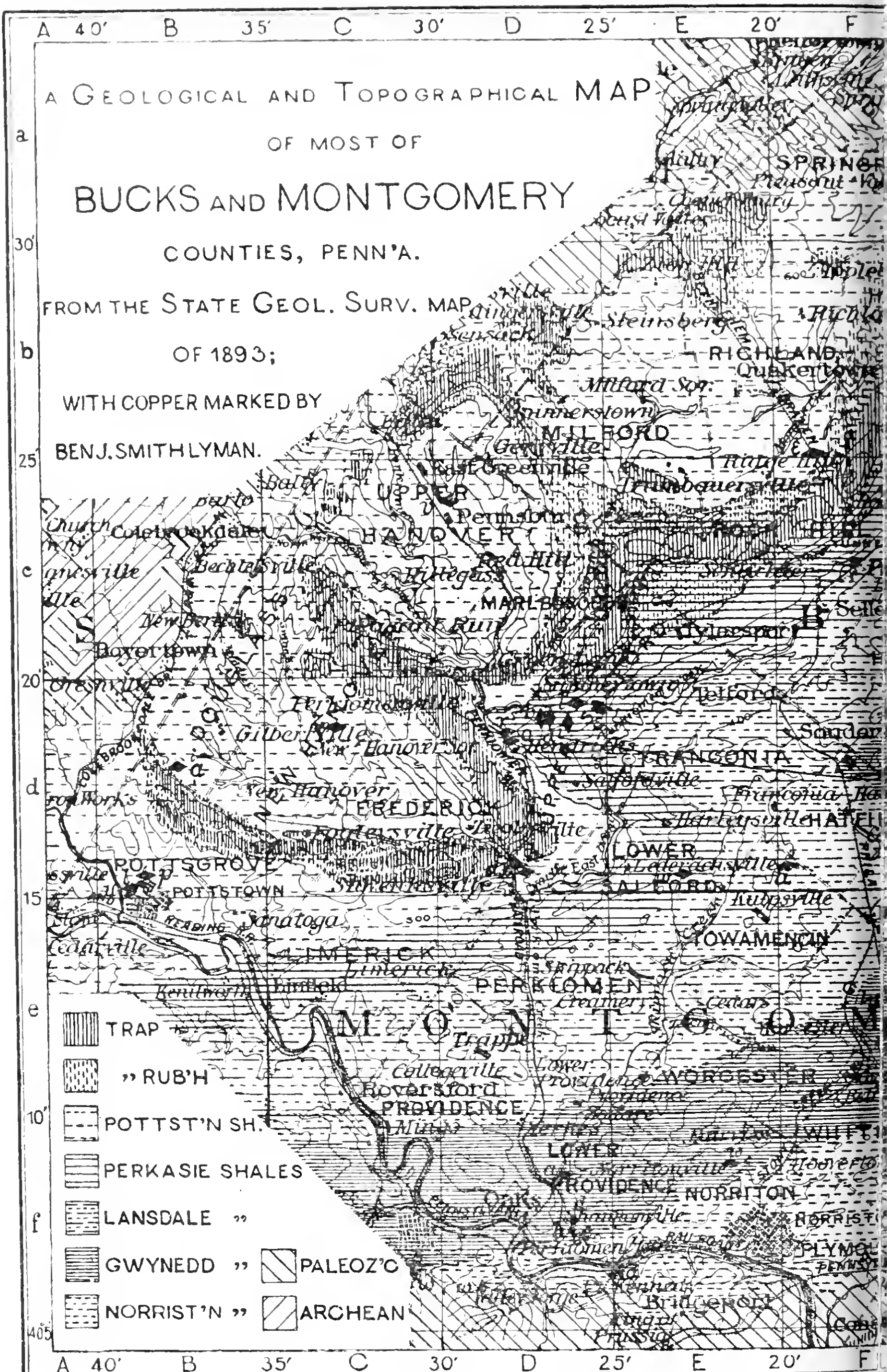
After the coins have thus been counted and weighed, they are tied up in linen bags and delivered to the treasurer in drafts of $5,000 each. The accuracy of the adjustment of the weight is so nice that there is rarely a deviation from the true standard weight of as much as $\frac{1}{100}$ of an ounce in any delivery of either gold or silver coin.

As a final precaution, the assayer is required by law to select at random one coin from every lot of $20,000; these are sealed in envelopes, numbered, and placed in a strong box provided with two locks; the key of one is kept by the treasurer and the other by the assayer. These sample pieces are called the "pyx." They remain sealed until the Commissioners appointed by the President assemble at the "annual assay" in February of each year to test their purity and weight; and it has rarely happened that any piece has been found to exceed the small limit of "tolerance" allowed by law.

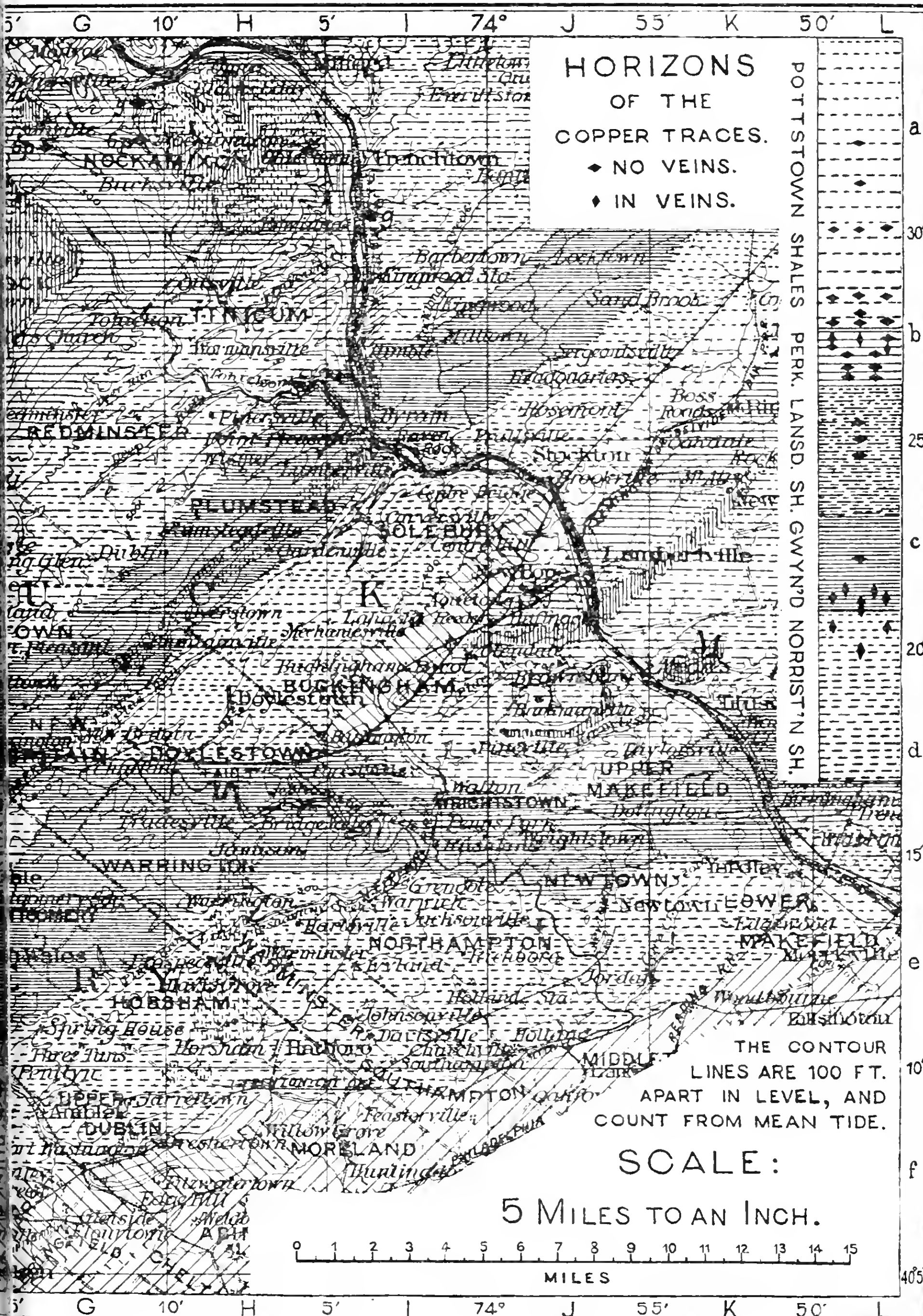
The manufacture of the dies for coin requires a high order of artistic and mechanical labor, involving the talent of the designer and the skill of the engraver and sculptor. A detailed description of the processes involved would necessarily extend this paper beyond the limits assigned to it. A brief outline must, therefore, suffice. The artist first makes a free sketch on paper, he then models his design in wax upon a glass plate, and it is probably five times the size intended for the coin; from this he takes a cast in plaster, which serves, when coated with plumbago, as a matrix, from which an electrotype in copper is obtained. The electrotype, after being finished by hand, is used as the model from which the steel die is cut by means of a reducing pantographic cutting machine, somewhat similar to those used for reproducing designs for steel rolls used in making printed fabrics. A traveling pointer attached to the long arm of a lever is caused to move back and forth over all portions of the raised model, and a steel drill attached to the short arm is thus caused to cut the design in a block of steel corresponding in all its details to the model, but reduced to the proper diameter for the coin; the stars and lettering are now added, and the whole is finally touched up by the hand.

This design is called the "Hub" or "Master die;" from it the coining dies are made and reproduced in any number required. A block of steel having been softened by annealing, is placed in a screw press carrying the "hub," and by a succession of blows, followed by frequent annealings, the die from which the coin is to be made is produced.

It is possible (owing to the great value of the raw material) to bring the processes involved in our gold and silver coinage to a perfection which would not, perhaps, be found profitable in any ordinary industry; and this fact, together with the national pride which is felt in the matter, should offer encouragement to the invention of all practicable methods of producing perfect work and preventing losses.


A GEOLOGICAL AND TOPOGRAPHICAL MAP
OF MOST OF
BUCKS AND MONTGOMERY
COUNTIES, PENN'A.
FROM THE STATE GEOL. SURV. MAP
OF 1893;
WITH COPPER MARKED BY
BENJ. SMITH LYMAN.
TRAP
" RUB'H
POTTST'N SH.
PERKASIE SHALES
LANSDALE "
GWYNEDD "
NORRIST'N "
PALEOZ'C
ARCHEAN

(*Lyman*)


HORIZONS
OF THE
COPPER TRACES.
NO VEINS.
IN VEINS.
POTTSTOWN SHALES PERK. LANSD. SH. GWYN'D NORRIST'N SH.
THE CONTOUR LINES ARE 100 FT. APART IN LEVEL, AND COUNT FROM MEAN TIDE.
SCALE:
5 MILES TO AN INCH.
MILES
TINICUM
PLUMSTEAD
SOLEBURY
BUCKINGHAM
DOYLESTOWN
WARRINGTON
WRIGHTSTOWN
UPPER MAKEFIELD
NEWTOWN
LOWER MAKEFIELD
NORTHAMPTON
HORSHAM
MORELAND
UPPER DUBLIN

graphically, with a small general columnar section of the same sets of beds.

The accompanying map shows in general precisely enough the place of each occurrence of traces of copper, and it is further chiefly necessary to indicate for each the rock-layer that contains the traces.

Each place is designated by three letters. The first letter indicates the five-minute space of longitude, as marked on the border of the map. The second letter indicates in like manner the latitude. The third letter is the one the place had on a certain page in the field note-book, and is marked on the map. Where necessary, in order to distinguish two places having the same letter, the number of the note-book page is given, at least the last digit. The places will be mentioned in the order of their geological horizons, beginning at the top.

### POTTSTOWN SHALES.

*Bda.*—Roadside, 1½ miles south of Gilbertsville; malachite traces in 2½ feet of grayish-red sandy shales, with mustard-seed pebbles, below 2½ feet of grayish-red and green mottled hard shales.

*Cdz.*—Northern roadside, 3 miles east of Gilbertsville; malachite traces in 5 feet of dark, dull red, sandy, hard shales.

*Bdp.*—Roadside, ⅛ mile north of northern edge of Pottstown; malachite traces in 4½ feet of grayish-green hard shales, a few yards north of two exposures of red shales.

*Bdu.*—James Gilbert's copper place, northwest edge of Pottstown; malachite traces in greenish-gray traces of old rubbish thrown out from a hole, now filled up, said to have been about 10 feet deep.

*Bdl.*—Roadside, northern edge of Pottstown; malachite traces in 1 foot of grayish-green, rather soft weathered shales, under a foot of grayish, rather dark red shales.

*Dcv.*—Roadside, east edge of Pennsburg; malachite traces in a foot of grayish-green hard shales with black specks, below about 16 feet of red shales, and above some 50 feet of red shales.

*Ddh.*—East bank of the Perkiomen, opposite Schwenksville; malachite specks in 1½ feet of reddish-gray hard shale, below 1 foot hidden, under 6 inches grayish green, hard shales at the top of long exposure, a few yards below an old abandoned quarry.

*Dda* and *b.*—Roadside, ⅛ mile east of Schwenksville, and east of the Perkiomen; malachite traces in 4-foot exposure of greenish- and reddish-gray hard shales with white specks. A hole formerly dug on each side of the road, both on the same bed, but with more malachite traces on the north side.

*Fbe.*—The Bunker Hill cut, on the North Pennsylvania Railroad, 2 miles southeast of Quakertown; malachite traces in 6 feet of greenish-gray hard shales, 160 feet, geologically, above the bottom of the section of the cutting, and below 4 feet of dark greenish-gray hard shales, and that below 60 feet of red shales, under 20 feet of trap, which is 234 feet below the top of the exposed section.

*Ddo.*—On the Perkiomen Railroad, half way between Hendricks' and Kratz Stations; malachite traces and pyrites specks in 6 inches of grayish-green, rather soft shales, below 53 feet and above 25 feet of red shales.

*Ddr.*—On the Perkiomen Railroad, 200 yards north of *Ddo;* and apparently the same bed, traces of malachite.

*Jcj.*—Roadside, 1¼ miles west of New Hope; malachite thin films in a 4-inch layer of dark gray, weathering bright green hard shales, below 13 feet and above 15 feet of red shales.

### PERKÁSIE SHALES.

*Ddd.*— A. Charles's first trial hole, in the field east of his house, ⅛ mile to the east of *Ddb;* about 1883. He says he found copper traces, but the hole is now all fallen in.

*Ddb.*—A. Charles's copper place, ½ mile south of Sumneytown; malachite traces and copper pyrites traces in a 7-inch vertical vein of clay and quartz in dark reddish-gray, calcareous very hard shale. Dug a little in 1885, but mainly in 1889, an open cut, perhaps 20 yards long by 4 yards wide, dug horizontally into the hillside. In the old rubbish specks

of copper pyrites are seen in hard, dark red shales, with rather more hematite.

*Ddl.*—Roadside, 1 mile east of Sumneytown, copper traces in ½ foot of dark reddish- and greenish-gray very hard shales, below some 7 feet of hidden, under 2 feet of dark reddish-gray hard shales.

*Gay.*—Roadside, just above, south of, Kintnersville, malachite traces at the bottom of 4 feet of grayish-green shales below 14 feet and above 10 feet of red shales.

*Ddi.*—A. Kober's copper place, 1 mile southeast of Sumneytown, and halfway between *Ddb* and *Dde.* Specimens of malachite, copper pyrites and azurite with calcite, thrown out here from a now inaccessible shaft said to be about 40 feet deep, and another, a dozen yards northeast "about 24 feet deep;" also a hole a dozen yards southwest of the first, said to be "50 feet deep." The vein is said to be 2 feet wide. A hole 9 feet deep, perhaps 100 yards to the south, has malachite traces in 9 feet of dark reddish- and greenish-gray very hard shales.

*Dde.*—On a crossroad, 1 mile east of *Ddb*, and 1½ miles east of Sumneytown; malachite traces in a foot of dark reddish-gray hard shales, and in ½ foot of the same, the two layers separated by unexposed layers.

*Ga6p.*—East side of road, at the north edge of Nockamixon village; malachite traces in 1 foot of grayish-green shales, below 5 feet of red shales at the top of the exposure.

*Fcl.*—Roadside, 1½ miles south of Keelersville; malachite traces and pyrites in 1½ feet of grayish-green hard shales, below 1½ feet and above 2 feet of red shales.

*Ga5p.*—Roadside, ¾ mile southeast of Bursonville, minute specks of copper pyrites in 2 feet of grayish-green hard sandy shales, with some minute white quartz pebbles, below 1 foot of lighter grayish-green pebbly shales, and above some 3 feet of hidden, above 2 feet of red shales, at the bottom of long exposures.

*Edw.*—Roadside quarry, 1½ miles east of Lederachsville; malachite traces in about 3 feet of green, hard shales, below about 8 feet of dark red, hard shales and above about 12 feet of reddish, dark gray, hard shales.

*Haa.*—Jacob Tettemer's copper place, 1 mile west of Uhlertown, a hole, now full of water, originally dug, it is said, 20 or 30 feet deep, about 1875, by Mr. Culmer, of Easton. Green malachite traces were found, such as are now to be seen among the shale bits in the cornfield around the hole.

LANSDALE SHALES.

*Fda.*—Roadside, 1¼ miles northeast of Kulpsville; bright malachite seams in 1 foot of green shales, below about 14 feet of red sandy shales, and above about 9 feet of like shales.

*Iag.*—Southeast side of Copper Creek, 1½ miles south of Frenchtown, N. J.; green malachite traces in 1 foot of green shales, below 6 inches of red shales exposed. A hole, said to be 20 or 30 feet deep, was dug here, on Mr. Hinkle's land, about 1883, and one on the opposite side of the creek, on Mr. Edgar Lance's land, said to be similar, with the green shale 3 feet thick. It is said one of the operators of the Flemington copper mine, abandoned some years ago, made the Lance opening, and pronounced the ore the same as theirs, but insufficient to work. Both holes were fallen in or full of water in 1889.

*Def.*—At the Collegeville quarry, ¾ mile north of Collegeville. The 13 feet of rather hard and shaly fine red sand rock at the bottom of the quarry, in 1889, underlying about 15 feet of green shales, has malachite traces and little holes, perhaps from the weathering out of pyrites. It is said about 6 inches of coal were found in the quarry, and it was burnt in the forge.

GWYNEDD SHALES.

*Dfa.*—On Dr. J. W. Griffith's farm, near the mouth of Skippack Creek, in Lower Providence Township, a piece of malachite was ploughed up in 1865; and it was afterwards sold by A. E. Griffith to the Mineralogical and Geological Section of the Academy of Natural Sciences. (Kindly communicated by Theo. D. Rand, Esq., Director of the Section.)

*Gdt.*—The abandoned New Galena mine, 3¼ miles northwest of Doylestown, full of water and inaccessible in 1889, but said to be 100 feet deep. Pieces of ore lying about contained specks of copper pyrites and traces of malachite, along with a little galena, a little zinc blende and much quartz. The country rock was apparently a blackish-gray hard shale. The mine appears to have been repeatedly tried for thirty-five years past.

*Cfb.*—The map, at p. 675, of Vol. II, of Rogers' Final Report, 1858, shows the Morris copper lode ½ mile south of Phœnixville. It was long since abandoned.

*Efw.*—Two miles northwest of Norristown and 1 mile east of Fairview. The occupant of the house near by says, 11th May, 1889, that in the field just below the house there is a well from which copper specimens were dug many years ago. But his father would not allow some desirous Philadelphia party to dig further.

*Dfd.*—Perkiomen Lead and Copper Mines, ⅜ mile northwest of Shannonville; a little copper pyrites and malachite traces in the rubbish (also azurite according to Dana) at the now inaccessible mines abandoned about 1868 and begun some twenty years earlier. The country rock appears to be a rather reddish-gray coarse sandrock. In the rubbish there was found with the copper, much quartz, but no blende nor galena.

*Dfh.*—Ecton Mines, ½ mile west of Shannonville. Mere traces of copper pyrites, with blende and galena in the rubbish of the old abandoned mines, apparently of the same date as the Perkiomen Lead and Copper Mines. The country rock appears also to be essentially the same, a light, reddish-gray, rather coarse sandrock; but is possibly a dark, reddish-gray, coarse, rather sandy micaceous shale.

*Cfc.*—The Shannonville copper lode, at Shannonville, marked on the map, at p. 675, of Vol. II, of Rogers' Report of 1858. Long ago abandoned.

### NORRISTOWN SHALES.

*Cfw.*—The abandoned, inaccessible Phœnixville Mines (the Wheatley, Brookdale, Chester County, Napoleon and

Petherick's Lead Mines), at the edge of the New Red, 1½ miles south of Phœnixville. Dana mentions as occurring here: chalcopyrite, native copper, malachite, azurite, indigo copper, black oxide of copper, phosphocalcite, as well as galena, blende and other lead and zinc ores, quartz, fluorite and a number of other minerals. Rogers (Final Report, 1858) enumerates some thirty minerals found in these mines. He points out that the veins within the New Red are characterized by containing ores of copper, while those within the gneiss bear lead as their principal metal, and zinc ores occur in both sets of lodes, but rather more in the copper lodes.

*Dfd.*—The Port Kennedy copper lode, at the village of that name, is marked on the map, at p. 675, Vol. II, of Rogers' Report of 1858. It must have been abandoned very long ago.

## MODE OF OCCURRENCE.

At Charles's copper place (*Ddb*) the copper ore occurs in a very narrow vein, cutting across the rockbed, and the ore seems to occur in a like manner at Kober's copper place (*Ddi*), at New Galena (*Gdt*), and at the Perkiomen (*Dfd*), Ecton (*Dfh*) and Phœnixville (*Cfw*) Mines, and at Shannonville and Port Kennedy; but at the twenty-seven other places the copper ore appears to be disseminated in small particles through the rockbeds without any perceptible vein. The columnar section, with the horizons of the copper traces marked in, makes it obvious that they occur most numerously in and near the Perkasie shales and the lower part of the Gwynedd shales. It is also clear that in a few cases the same horizon has been found to bear traces of copper at more than one distant point. The striking feature of the grouping of the copper-bearing horizons is that they occur principally in or near those two sets of shales that contain black or dark-colored beds. The explanation readily suggests itself that carbonaceous matter has by reduction produced copper sulphide from copper sulphate that was in the water from which the shales were deposited, or by which they were permeated from below

through the few narrow fissures observed, or otherwise. The copper sulphide may, by the oxidation and carbonating of weathering, have produced the malachite so frequently observed on the outcrop. This deposition of the copper from solution through precipitation by the carbon of organic matter agrees well with the most reasonable explanation of the occurrence of copper ore in the permian beds of the Mansfeld, of Texas and of Nova Scotia (see E. J. Schmitz, Trans. Am. Inst. M'g Eng'rs, Vol. XXVI, p. 97, and H. Louis, same volume, p. 1057, 1897). The somewhat prevalent greenish color of the Perkasie shales, as well as the dark-gray color common in the lower part of the Gwynedd shales, would also be generally, and apparently with perfect reason, attributed to the agency of organic matter that has reduced the red peroxide of iron so strongly coloring the greatly predominant red shales of the rest of the New Red, and has given rise to the gray, green or blue salts of the protoxide of iron. The several copper horizons outside of those two comparatively dark sets of shales may likewise occur in connection with somewhat more isolated greenish or dark shale beds; for darker or greenish beds do occur here and there among the prevalent red ones. Even if the copper traces be found within red beds, as they appear to be in some cases, the reduction and precipitation may have been caused by organic matter, either present in those very beds or in adjacent darker or more greenish beds, acting upon the waters soaking through the different layers. In some cases it may have been single, scattered plants that have caused the precipitation of the copper, without the power to affect the color of the main body of the shale bed.

It appears then that the mere traces of copper in Bucks and Montgomery Counties, wholly unworkable as they are, yet have some use in indicating by their mode of occurrence the origin of many copper ores, corroborating what has been inferred from the deposits of the Mansfeld, Texas, Nova Scotia and elsewhere.

# ELECTRICAL SECTION.

*Stated Meeting, October 24, 1898.*

## THERMO-ELECTRIC AND GALVANIC ACTIONS COMPARED.

BY CHARLES J. REED.

In addition to the methods necessitating mechanical motion, I believe there are at the present time recognized two other distinct processes of generating an electric current. These processes are the electro-chemical and the thermo-electric. While these two processes are of an entirely different nature, it appears that the electro-chemical or electrolytic process can never take place without being accompanied and modified to some extent by the thermo-electric process. The thermo-electric process may in a certain kind of apparatus take place without any chemical or electrolytic reaction. In another kind of apparatus the thermo-electric process is always accompanied and its results modified by chemical change. This concurrence of the two processes, which is entirely accidental and due to the nature of the materials constituting the apparatus, has in some cases given rise to a difference of opinion as to whether the action in a particular case is electro-chemical or thermo-electric.

It is on account of this difference of opinion, which I believe should not exist, that your attention is asked this evening to the consideration of certain thermo-electric and certain galvanic actions that have been subject to this confusion.

In order to discuss these actions intelligently, it is necessary to define at the outset exactly what is meant by galvanic and by thermo-electric action, and to indicate the general characters by which it has been customary to distinguish them.

We shall use the term *thermo-electric*, to include any process by which external heat is continuously absorbed directly into a closed circuit and simultaneously evolved as electrical energy in that circuit, that is, any process in which the electrical energy comes entirely from the external heat by direct absorption and in which there is no limit to the quantity of heat that may be transformed.

The term *galvanic*, we shall use to designate only that process, by which the energy liberated in a chemical change is evolved as electrical energy and in which chemical change is the only source of the energy. The source of energy is not external to the circuit, but solely in the chemical energy of the materials constituting the circuit. Any electrical energy evolved by galvanic action must leave the circuit with less potential energy in its final state than it had at the beginning and must be limited in quantity to the available energy of chemical reaction in the materials constituting the circuit. The distinction to be kept clearly in mind between the processes is that in one case the source is external to the circuit, while in the other it is internal.

The opinion has recently been advanced by Mr. C. P. Steinmetz that chemical action may continue to evolve electrical energy indefinitely, provided heat or some other form of energy is simultaneously applied to regenerate the chemical energy and thus maintain the materials in their initial state. This supposition is not only incapable of experimental proof, but seems to have no particular significance, if true. To say that a revolving shaft, which receives motion from an engine and transmits it by means of gears and belts to other machinery, evolves energy or is, in the sense we are considering, the source of energy, is absurd, and the assertion is not justified by the saying the motion of the shaft is continually regenerated by the engine, so that its final and initial states are identical. The shaft can evidently impart only the energy it has previously absorbed from the engine. If it were a source of any of the energy, it would have power to at least start the motion and continue it for a short time without the help of the engine. For the same reason a body or system cannot evolve energy

by a chemical change originating within the system, which requires simultaneous and continuous reversal by the absorption of an equivalent external energy, and which leaves the initial and final chemical states identical.

I shall premise, therefore, that no body or system can be the origin or source of energy or of any process evolving energy, unless in its final state its energy is less than in its initial state. If we accept this premise, we establish a criterion, by which the distinction between galvanic and thermo-electric action may be invariably made.

It is not necessary this evening to trace the progress and history of the laws governing these processes, which have been brought to light during the past three-quarters of a century, from Seebeck and Faraday to Kelvin and Tait. It

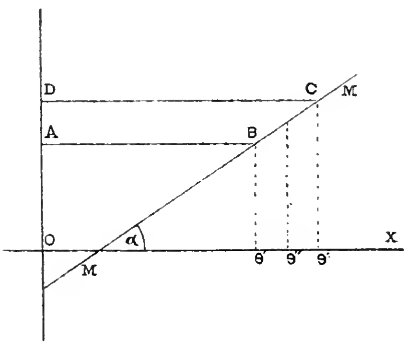



FIG. 1.

will be sufficient for our purpose to keep before us a few of the most important of these laws.

*Thermo-electric Action.*—With reference to thermo-electric action there are recognized two distinct processes or kinds of transformation, known as the Peltier effect and the Thomson (Kelvin) effect. The various thermo-electric effects due to irregularities in the structure or molecular condition of the bodies experimented upon, such as have been pointed out by Magnus, Kelvin and Le Roux, all come under the Peltier and Thomson effects.

Kelvin found that a positive current in an unequally heated iron conductor evolves heat in passing from a colder to a hotter part of the conductor and absorbs heat under

the same conditions in a copper conductor, and, conversely, that, in passing from a hotter to a colder portion, these actions are reversed. Professor Tait showed experimentally that the coefficient of this effect is proportional to the mean absolute temperature. If a curve be drawn, whose abscissa is the absolute temperature and ordinate, the thermo-electric power of a metal with respect to lead (in which the Thomson effect appears to be zero), the curve is found to be a straight line.

*Fig. 1* shows Tait's diagram of thermo-electric power. The tangent of the angle, $a$, which the curve of thermo-electric power, $MM$, of any metal with respect to lead makes with the axis, $OX$, is the coefficient of the Thomson

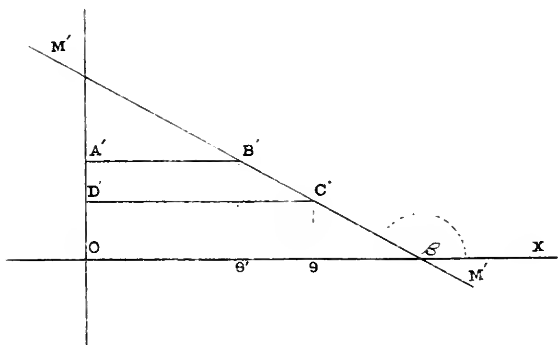



FIG. 2.

effect in that metal. The Thomson effect in the metal, if its terminals are at the temperatures, $\theta$ and $\theta'$, is the area, $ABCD$. It will be seen that this area is, for a given difference of temperature, proportional to the mean absolute temperature, $\theta''$, and for a given mean absolute temperature, is proportional to the difference of temperature between its terminals. That is, the area representing this effect is the rectangle of the mean absolute temperature and the difference of temperature into the tangent of the angle, $a$.

In *Fig. 2* $tan\ \beta$ is negative, and the Thomson effect, $A'B'C'D'$, is in the opposite direction.

*Fig. 3* shows the diagram of the junction of two conductors, whose curves of thermo-electric power are $MM$ and

$M'M'$, whose junction is at temperature, $\theta_0$, and free ends at temperature, $\theta'$. Here the electromotive force due to the Thomson effect in the two metals is the sum of the areas, *ABCD* and *A'B'C'D'*, and both tend to produce a current in the same direction in the circuit.

The Peltier effect, another kind of thermo-electric inversion, unlike the Thomson effect, does not occur in a single conductor, but at the junction of two dissimilar conductors. Peltier discovered that when an electric current crosses the junction of two conductors in one direction the

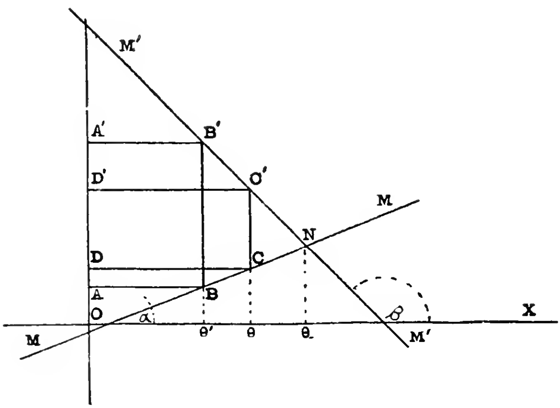



FIG. 3.

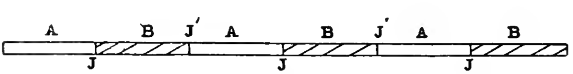



FIG. 4.

junction is heated and when it crosses in the opposite direction the junction is cooled. This is the inverse of the effect discovered by Seebeck, the development of electromotive force in one direction when the junction is heated and in the opposite direction when it is cooled.

*Fig. 4* represents a series of similar conductors, *A*, of one substance, joined by similar alternate conductors, *B*, of another substance. Assume that a current in passing through this series from *B* to *A* across the junctions, *J*, causes those junctions to be cooled. An electromotive force tending to

increase the current is developed at $J$, while at $J'$ heat is evolved and a counter electromotive force developed. If the junctions, $J$ and $J'$, be maintained at the same temperature, the absorption at $J$ equals the evolution of heat at $J'$, and the Peltier effects balance each other. At the same time there could be no Thomson effect in either conductor. The electromotive force is always the algebraic sum of the Thomson and Peltier effects, and is well shown in Tait's diagram.

Referring again to *Fig. 3*, Kelvin and Tait have shown that the Peltier effect of a hot junction at temperature, $\theta$, is the rectangle, $D'\ C'\ D\ C$, or

$$P = (tan\ \alpha - tan\ \beta)\ (\theta_\circ - \theta)\ \theta \tag{1}$$

$\theta_\circ$ being the temperature at which the curves of thermo-electric power intersect. Similarly the Peltier effect at the cold junction at temperature, $\theta'$, is

$$P = (tan\ \alpha - tan\ \beta)\ (\theta_\circ - \theta')\ \theta',$$

or the rectangle, $A'\ B'\ B\ A$. The algebraic sum of the Thomson and Peltier effects is the area, $B'\ C'\ C\ B$, or

$$E. = (tan\ \alpha - tan\ \beta)\ (\theta - \theta')\left[\theta_\circ - \frac{1}{2}(\theta + \theta')\right] \tag{2}$$

The E.M.F. will become zero when

$$\theta_\circ = \frac{1}{2}(\theta + \theta'),$$

that is, when the mean temperature of the junctions is $\theta_\circ$, as shown in *Fig. 5*. On this account $\theta_\circ$ is called the "neutral point."

It is evident that the E.M.F. may also be expressed in terms of $P$ and $P'$, the Peltier effects per unit of current per unit of time at the hot and cold junctions respectively, since

$$E. = \frac{1}{2}(B\ B' + C\ C')(\theta - \theta') = \frac{1}{2}\left(\frac{P'}{\theta'} + \frac{P}{\theta}\right)(\theta - \theta')$$

When $\theta' = \theta_\circ$ we have, collecting constants,

$$K\ E = \frac{\theta - \theta'}{\theta}$$

As this is also the expression for the maximum efficiency of any thermo-dynamic transformation, it follows that under no circumstances can the efficiency of a thermo-electric apparatus be greater than when either the hot or the cold junction is maintained at the neutral point. With one of the junctions at the neutral point we see from (2) that the electromotive force is proportional to the square of the difference in temperature between the junctions, or

$$E = -\frac{1}{2}(tan\ \beta - tan\ \alpha)(\theta - \theta')^2$$

In *Fig. 5* the electromotive force is the area of the triangle, $C\ C'\ N$, which is evidently proportional to the square of its altitude $\theta - \theta'$.

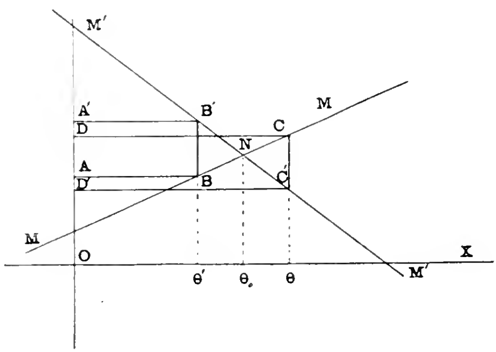



FIG. 5.

The experiments of Kelvin and Tait, on which these conclusions are founded, were confined to metals and alloys, but there is no reason for supposing that these effects exist only in metallic conductors. The same reasoning, which led Kelvin to the prediction of the Thomson effect in metallic conductors, requires also the existence of both of these effects in any conductor, in which one of the effects is possible. The existence of these effects in electrolytes has been conclusively established by Bouty and others.

*Galvanic Action.*—Galvanic action may be considered to be identical with electrolysis. It is merely a particular case of electrolysis, in which the chemical change evolves energy, whereas, what we ordinarily call electrolysis re-

quires external energy to produce the chemical change. This may be expressed by saying that electro-chemical action is also a reversible effect or mode of transformation, and that when latent or chemical energy becomes electrical energy we call the action galvanic, but when the process is reversed and electrical energy becomes latent or chemical, we call the action electrolytic. Theoretically every galvanic action is reversible by an electric current in the opposite direction from an external source, and every electrolytic action is reversible as a galvanic action. This reversal, however, is not often practicable, because generally the products of the change in either direction are lost or become contaminated or enter into secondary reactions with extraneous substances. When this reversal is practicable and nearly perfect, the apparatus is called an accumulator or storage battery.

From this it will be seen that, while galvanic action always necessitates chemical change, chemical change is not always sufficient to produce galvanic action. Galvanic action always necessitates certain conditions, among which are the following:

(1) The chemical reagents concerned in an electro-chemical reaction must be electric conductors, and form part of the circuit in which the electrical energy is developed. A non-conductor, although intimately mixed or dissolved in the reagents can take no part in the reaction.

(2) At least one of the conductors must be a compound and an electrolyte. The reagents must disappear and the products of the reaction must appear at the terminals of this electrolyte; that is, at the points where the electric current enters and leaves the electrolyte.

(3) The chemical reaction must be exothermic, that is, must evolve energy.

A further condition seems to be that the electrolyte shall not be a single compound, but a solution of one compound in another.

The ordinary type of galvanic cell, shown in *Fig. 6*, consists of two solid conductors, *A* and *C*, connected by an electrolyte, *E*. In such an apparatus it is necessary that at

least one of the solid conductors shall be capable of acting chemically on the electrolyte.

A less common type of galvanic cell is shown in *Fig. 7*, consisting of two different electrolytes, $E$ and $E'$, in contact with each other and also in contact with terminal conductors or electrodes, $e$ and $e'$. In this type of cell the electrodes, $e$ and $e'$, may be of the same material and both may be chemically inert to the electrolytes, but the electrolytes must be capable of acting chemically on each other.

There are two important laws governing electrolytic and galvanic action. One relates to the quantity of matter and the other to the quantity of energy concerned in the reaction. The first is known as Faraday's law of electro-chemical equivalents. It states that the quantity of electric current passing through a galvanic or electrolytic cell, which corresponds to a change of one unit of valence in a chemical equivalent of *one* substance, corresponds also to a change of one unit of valence in a chemical equivalent of *any* substance. This law was demonstrated experimentally by Faraday for very many substances, but it may also be deduced as a necessary consequence of the atomic theory and the theory of the conservation of energy.

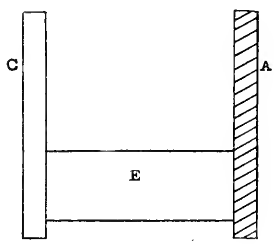


Fig. 6

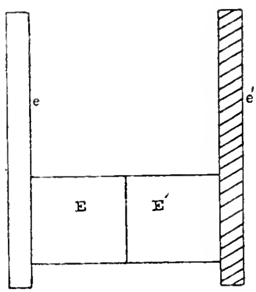


Fig. 7.

Of equal importance is the law governing the electromotive force of an electro-chemical reaction. It was deduced from Faraday's law and the principle of conservation by Kelvin and published by him in 1851. It states that the electromotive force of any electro-chemical reaction is, in absolute measure, equal to the dynamical equivalent of the

chemical action that takes place during the passage of a unit current for a unit of time.

I have taken the time to rehearse these general statements in regard to thermo-electric and galvanic action, in order that you may not mistake my premises and that you may at the same time have clearly in mind the criterion I shall use in determining whether a reaction is galvanic or thermo-electric.

When a system spontaneously undergoes a chemical change evolving electrical energy without the application of external heat, and by the mere juxtaposition of its parts or elements, there can be no doubt that the energy is evolved as a result of the chemical change, and that, if no heat is allowed during the process to enter or leave the system and no change of temperature occurs within the system, chemical action is the *only* source of the energy. The chemical energy of the system will in this case be less in the final than in the initial state.

When, on the other hand, electrical energy is evolved only during the application of external heat, and when the chemical state at the beginning is identical with the chemical state at any succeeding period, the electrical energy must come solely from the heat absorbed directly into the circuit during its action and the process is thermo-electric.

The initial and final chemical states may be different and yet the process be entirely thermo-electric. This evidently occurs whenever, by the application of heat, electrical energy is evolved and the final chemical state is one of greater chemical or potential energy than the initial. Here the heat energy transformed must equal the electrical energy evolved plus the chemical energy stored or accumulated. The storing of the chemical energy may be due to a separate thermo-chemical process accompanying the thermo-electric process, or it may be due to an electrolytic action resulting from the passage of the thermo-electric current through the materials constituting the closed circuit.

When by the application of external heat a chemical change occurs, evolving electrical energy in excess of the energy available from the chemical reaction and also in

excess of the energy absorbed as heat, the electromotive force of the circuit is always the sum of the thermo-electromotive force added to the electromotive force of the electrochemical reaction, and the transformation is the result of the simultaneous action of both processes.

When a chemical change in a system results in the evolution of electrical energy and heat (exclusive of incidental losses, such as the heat due to the Joule effect), the difference between the chemical energy of the initial and final states is equal to the electrical energy plus the heat evolved by thermo-electric inversion.

The necessary concurrence of thermo-electric action with all cases of galvanic action may be predicted from the nature of the apparatus.

*Fig. 8* represents diagrammatically the apparatus required for thermo-electric action. It consists of two con-

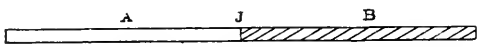



FIG. 8.

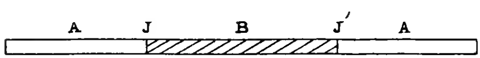



FIG. 9.

ductors, *A* and *B*, of different substances (or one substance in two different molecular states), electrically united at a point called the junction. *Fig. 9* represents diagrammatically the apparatus required for galvanic action, and consists of at least three conductors of different kinds electrically connected in series, of which at least one, *B*, must, as previously stated, be an electrolyte. It is evident from an inspection of these diagrams that the apparatus necessary for galvanic action always includes the apparatus necessary for thermo-electric action, that is, one or more junctions of dissimilar conductors; and that a galvanic current cannot flow through such an apparatus without causing thermoelectric inversion, both at the junctions and throughout the mass of the several conductors. We have reason to believe, therefore, that no galvanic battery of any form can give an

electric current without that current being affected to some extent by thermo-electric action within the cell. This action may result in an increased or a diminished electromotive force, or possibly an increase in certain parts of the cell and an equal decrease in other parts. It has also been shown by Helmholtz that the formula for the electromotive force of an electro-chemical reaction, as stated by Kelvin, requires a correction due to the change of entropy the system undergoes, which necessitates that the system shall during action either undergo a change of temperature or absorb or evolve heat in accordance with the formula for thermo-electric inversion, as expressed in terms of the Peltier effect.

It has sometimes been supposed that a galvanic battery may be constituted of less than three different substances. That this is impossible is evident from *Fig. 10*, which repre-

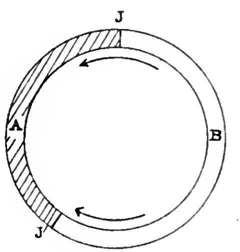



FIG. 10.

sents such a circuit in the form of a closed ring of uniform temperature, made up of two conductors, *A* and *B*, joined at the points, *J* and *J'*, one being an electrolyte. Galvanic action must originate in a chemical change between the conductors constituting the circuit, that is, between *A* and *B*, and must take place at the terminals of the electrolyte, *J* and *J'*. But the chemical conditions must be different at these two points, which is contrary to the supposition that there are only two substances. Let us assume that at *J* a chemical change occurs producing an E.M.F. tending to send a current in the direction, *J A*, indicated by the arrow at the top of the diagram. By hypothesis the chemical conditions at *J'* are identical with those at *J*, and there is also an E.M.F. at *J'* tending to send a current in the direction, *J' A*, indi-

cated by the arrow at the bottom. These two electromotive forces, being equal and opposite, can result in no current. On heating or cooling either $J$ or $J'$, we invariably get a current by thermo-electric inversion. The fact that certain thermo-electric couples of this form, in which one conductor is an electrolyte, give a very high E.M.F., has led to the belief that the current is due to chemical action and that the heat merely enables the chemical action to take place. But it is evident that any electro-chemical change which may occur at $J$, causing a current to flow around the ring in either direction, must be electrolytically reversed at $J'$ with an absorption of the same amount of energy as that evolved at $J$. Any electrical energy evolved from such an

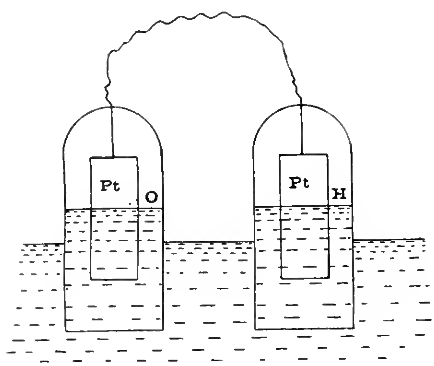



FIG. 11.

arrangement must, therefore, originate in the heat applied and not in the chemical change. To deny this, is to deny that a result originates in its cause. The cause of the electrical energy is the heat applied, and the quantity is equivalent to the heat absorbed.

There are some deceptive cases, in which galvanic action apparently results from the juxtaposition of only two conductors, but this is only apparent. We may cite as an example of this kind the so-called gas battery, in which two platinum plates are immersed in dilute sulphuric acid, one of the plates being surrounded by hydrogen gas and the other by oxygen, as shown in *Fig. 11*. In this battery, which gives an electromotive force of about one volt, the circuit

consists apparently of nothing but platinum and the dilute acid, but in reality it consists of a compound of hydrogen and platinum and a compound of oxygen and platinum, both in contact with the electrolyte. It has been conclusively shown that platinum forms definite chemical compounds with oxygen and with hydrogen on coming in contact with these gases at ordinary temperatures. If carbon rods be substituted for the platinum plates, no galvanic action results, unless the gases have been produced electrolytically, in which case other chemical reagents are simultaneously generated in the solution at one of the electrodes and we have present at least three conductors. All other cases of galvanic circuits consisting of apparently only two conductors will be found to really contain at least three.

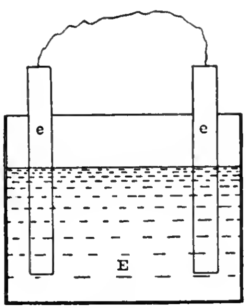



FIG. 12.

*Fig. 12* shows an interesting type of thermo-electric cell, which has been mistaken for a galvanic cell. It consists of two similar conductors, *e* and *e'*, of the same substance, both in contact with the electrolyte, *E*. This it will be seen cannot at any temperature or under any circumstances constitute a galvanic cell, whatever may be the electrolyte or the substance composing the electrodes. But with certain electrodes and electrolytes it does constitute a most powerful thermo-electric apparatus. With a fused alkali hydrate as the electrolyte and iron electrodes the *E.M.F.* at temperatures between 500° and 700° C. may be as high as 1.2 volts. When the circuit is closed a current is compelled to pass through the electrolyte. This by Faraday's law necessarily

causes electrolysis, oxidizing iron at one electrode and reducing iron (from solution as oxide in the alkali) at the other electrode, the initial and final chemical states being identical, exactly as in the electrolytic refining of copper. *Fig. 13* shows another thermo-electric cell in which electrolysis is produced by the thermo-electric current, and in which the final chemical state contains more energy than the initial. In other words a thermo-electric current was produced which operated an electro-magnet in one part of the circuit and simultaneously stored up chemical energy within the cell itself. The apparatus consisted of a silver crucible, *S*, containing chemically pure sodium hydrate, maintained at a

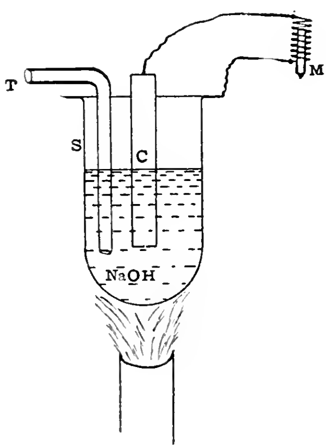



FIG. 13.

temperature of about 700° C. by a gas-flame and a carbon rod, *C*. The silver cup and carbon rod constituted the electrodes and were connected through the electro-magnet, *M*. A strong current of air was at the same time blown into the electrolyte through a silver tube, *T*. On closing the circuit a current of about .03 ampere caused oxidation of the carbon rod and reduction of metallic sodium at the walls of the crucible. The liberation of sodium rapidly increased and its combustion on reaching the air became so violent at the end of thirty minutes that the operation had to be discontinued. The crucible was found to be so thoroughly impreg-

nated with sodium at the bottom that it was spongy and useless and it crumbled with slight pressure, as you may observe by examining its remains. The electrolytic chemical change produced by the current is expressed in the following equation:

$$C + 3\ NaOH = Na_2CO_3 + Na + 3\ H.$$

The formation heat of $Na_2CO_3$ is 271,000 calories, while that of $3NaOH$ is 306,000. Hence, to produce the difference between the initial and final states, required the absorption of 35,000 calories from the heat applied, in addition to that required to produce the electrical energy expended in the rest of the circuit.

The Jacques "carbon consuming battery" differs from this only in the substitution of an iron pot for the silver cup and commercial sodium-hydrate for the chemically pure.

*Fig. 12* shows the conditions in an ordinary electro-plating or in a copper refining cell. Here the initial and final chemical states are identical, the energy evolved by the solution of the metal at the anode being exactly equal to that absorbed by its reduction at the cathode, the resistance of the cell and the transfer of matter from one electrode to the other requiring a small electromotive force from an external source. This electromotive force may, however, be very minute and may be generated thermo-electrically within the cell by raising the temperature of one electrode above that of the other. This may be done by making one electrode in the form of a tube, through which steam or hot water is conducted. Copper is deposited from a sulphate solution on the hot electrode and dissolved from the cold. In the sample here exhibited the deposit was formed in about twelve hours, the thermo-electromotive force being from ·04 to ·06 volt.

Another instructive illustration of thermo-electric action I hope to show you in the apparatus here exhibited. It consists, as shown in *Fig. 14*, of a zinc tray, *Z*, containing a strong solution of zinc chloride, to the bottom of which the heat of a gas-flame is applied. Into the heated solution of zinc chloride we immerse a clean strip of copper, *C*, without

allowing it to touch the tray. On withdrawing it we find that it is unchanged, there being no chemical reaction between the metallic copper and the zinc chloride. Immersing it again and bringing it in contact with the tray at any point, we find, on withdrawing it, that it is covered with a very smooth and perfect deposit of metallic zinc. This deposit is so perfect and intimate with the copper that on slightly heating it in the flame the two metals unite and form a very fine coating of brass. Iron and other metals not dissolved by the solution may be plated by the same process. The initial and final chemical states are here identical, and the action is thermo-electric. It is evident from *Fig. 14* that the metallic strip, *C*, is at a lower temperature than the tray, since it receives its heat only from the electrolyte, which in

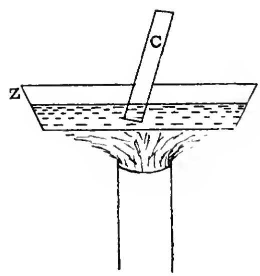



FIG. 14.

turn receives heat only from the tray. The junction of the electrolyte with the tray is, therefore, necessarily hotter than its junction with the copper strip. A galvanometer connected between the tray and the copper strip shows an E.M.F. of several tenths of a volt in the direction tending to deposit zinc on the copper, and on closing the circuit the deposition instantly takes place. This action is in no-wise similar to the action of the copper-zinc galvanic battery, or to the deposition of metallic copper from solution on metallic zinc. In that case the same metals are present, but they are connected by a salt of copper instead of a salt of zinc. Metallic zinc acts chemically on all salts of copper by substitution, evolving in the reaction a large amount of chemical energy, which must escape either as heat or elec-

trical energy, and leave the final chemical state with less energy than the initial. But metallic copper cannot act by substitution on salts of zinc. Such a reaction would require the storing of the chemical energy which is evolved by the action of zinc on a copper salt. In our experiment the copper acts merely as a conductor, and is immediately covered up with zinc, but in the copper-zinc battery one metal goes out of solution and a more highly electro-positive metal takes its place. The copper-zinc cell in its final and completely exhausted state is identical with this apparatus in its initial state and in every succeeding state. In it there is no possibility of evolving energy from chemical action, but by the continued application of heat it may be made to evolve electrical energy for an indefinite period. The mechanical destruction of the apparatus by the continued transfer of zinc from one electrode to the other may be theoretically prevented by applying the heat to the opposite electrode after a suitable interval of time.

By substituting a solution of zinc sulphate in *Fig. 14* for the zinc chloride we no longer obtain the deposit of zinc on the copper strip, showing apparently that the direction of the current is not the same for the two electrolytes.

Some additional experiments, however, suggested by Mr. Carl Hering and performed with his assistance, prove that the direction of the current is the same whether the chloride or sulphate of zinc is used, the direction being that which tends to deposit zinc on the copper, though the deposit can be obtained on a copper strip with zinc sulphate in a zinc tray only with difficulty. The reason is found in the great tendency of the zinc to redissolve and the copper to oxidize in contact with the sulphate solution. Nevertheless, the electromotive force, as shown by a voltmeter, is about ·6 volt, and is always in the direction tending to deposit zinc on the copper.

## DISCUSSION.

A. E. KENNELLY:—As I understand this interesting paper, it deals with the question as to whether a cell containing a pair of elements and an electrolyte, and entirely

dependent for its electromotive force upon a supply of heat from an external source, is a voltaic or a thermo-electric combination. As pointed out in the paper, a voltaic cell is generally understood to deliver its electric energy at the expense of internal chemical energy; while a thermo-electric cell is generally understood to deliver its electric energy at the expense of externally supplied heat. Under ordinary conditions, therefore, it is usually easy to differentiate between the two types. Every voltaic cell at work is, however, always accompanied by thermo-electric action, and every thermo-electric cell containing an electrolyte is necessarily accompanied, when at work, by electrolytic action. Consequently, it may happen in particular cases, that the thermo-electric and voltaic actions in one and the same cell may be so blended as to make it difficult to determine on first inspection whether a cell belongs to the one type or to the other. Moreover, it is possible in a cell whose elements are similar in their electro-chemical condition at normal temperatures, that a dissimilarity may be produced by the application of heat in a dissymmetrical manner, so that one element, heated to a higher temperature than the other, might become endowed with chemical affinity for the electrolyte by virtue of the heat energy received. In every such possible case, however, there would necessarily remain this criterion as to the nature of the actions involved, viz.: that thermo-electric action is necessarily limited in its efficiency of transformation by the range of temperatures employed, according to the formula

$$\frac{T-t}{T};$$

whereas, voltaic action is theoretically capable of 100 per cent. efficiency. If, therefore, the losses of energy occurring in the cell can be measured, it becomes possible to ascertain whether the cell is a heat-engine or thermo-electric combination absorbing heat at one temperature and rejecting part of the heat at a lower temperature; or, whether it is a thermo-chemical engine or voltaic cell in which thermal energy is first commuted into chemical energy, and

this, in its turn, into electrical energy; or, whether it is both a thermo-electric and a thermo-chemical cell.

I do not think, therefore, that it can be demonstrated, in a general way, without experimental observation, that a cell depending upon heat for its energy is necessarily only a thermo-electric cell.

The coating of zinc upon the surface of the copper which is found in the interesting experiment we have witnessed, seems to possess remarkable properties, since it is said to be only with difficulty attacked by hydrochloric acid. It seems possible, however, that the coating of zinc being so thin, the zinc is in such close juxtaposition with the copper as to virtually partake of the nature of an alloy. If this were the case, the distinctive property should be lost as soon as the coating acquires an appreciable thickness.

PROF. JOSEPH W. RICHARDS:—I cannot accept Mr. Reed's conclusions in regard to the thermo-electric character of the Jacques carbon consuming battery, for the following reasons:

In the iron-soda cell, *Fig. 12*, p. 14, I fail to recognize any grounds for predicating thermo-electric action at all, for where are the unequally heated parts which are the essence of the generation of a thermo-electric current? With the Peltier effect, which concerns the conversion of electric energy into heat at a junction of two unlike conductors, we have nothing to do, when discussing the *generation* of the current itself. With the converse of the Peltier effect, Seebeck's discovery of the production of electromotive force at *two unequally* heated junctions, and Thompson's discovery of production of electromotive force in one unequally heated conductor, we are rightly concerned; but how can they be seriously considered in an apparatus *all parts of which are at the same temperature.* The occurrence of such phenomena in such an apparatus is excluded by the very definition of the phenomena themselves.

In the cell as there described, the electrolyte and electrodes are all at one temperature; therefore any thermo-electric effect produced by heating the junction of electrolyte and electrode on the one side, is neutralized by the

exactly opposite effect at the other side; and if we conceive the electrodes to be cooler out of the electrolyte than in it, yet any Thompson effect thus engendered in the body of one electrode would be neutralized by the exactly opposite effect at the other side. There are thus, as far as I can see, absolutely no grounds for predicating any thermo-electric effect, and, therefore, the cause of the current *must* be chemical action. I have conceived a possible chemical reaction in this case, but the data on which it rests are not quite certain enough to merit bringing the matter into this discussion. Perhaps a better explanation that I have in mind may be suggested by someone who, as I am, is convinced that a thermo-electric effect is absolutely out of question.

Coming nearer to the "Jacques cell," the reasons for assuming thermo-electric action in this case are very nearly as baseless as in the preceding cell. There is, theoretically, no unequal heating of any junctions or parts, and so it cannot in principle be a thermo-electric apparatus. On the other hand, there is present abundant material for supplying a chemical explanation of the action. Is it not well-known that pyrophoric iron will reduce caustic soda at redness? Was not Castner's original sodium process founded on the reduction of fused caustic soda by carbon weighted down by iron, and the temperature of a pot in which the reaction was in full operation was once measured at 823° C.? Did not Netto produce tons of sodium by trickling fused caustic soda over coke, in a retort heated to redness? There is thus abundant reason for assuming that at about 700° C., as given, the carbon simply acts reducingly on the caustic, separating out sodium electrolytically on the opposite electrode, the surplus energy of the reaction supplying the motive power of the current observed.

The reason why the thermal data do not correspond, is that those given by Mr. Reed are for combinations at 17° C. What the heats of formation of caustic soda and carbonate are at 700° we do not know, but it *is* known that carbon can reduce caustic soda at redness, and carbonate only at whiteness. Everything we do know points to the fact that the

heat of formation of the caustic soda decreases rapidly with the temperature, and more rapidly than that of the carbonate. If we only knew these exact heats of formation at 700° we could calculate the energy of the chemical reaction in this cell, and would then have the theoretical explanation of what we know as an observed fact.

C. J. REED:—The reason given by Dr. Kennelly for supposing that the action of the zinc-chloride and similar cells may not be thermo-electric, is that the efficiency of transformation of such an apparatus could not exceed $\frac{T-t}{T}$ if the process is thermo-electric. This is undoubtedly true and, for exactly the same reason, the process could not be thermo-chemical. The conversion of heat into chemical energy by absorption in an endothermic reaction, or into any higher form by any process whatever, comes under the same limitations. If there is any voltaic transformation of the chemical energy so stored or formed, it must necessarily be subsequent to the thermo-chemical or storing process, and the total efficiency of the two processes would be still less than that of either the thermo-chemical or the thermo-electric alone. Inasmuch as there is no record of any measurements having ever been made, that show an efficiency even remotely approaching the theoretical limit, it seems to be unnecessary to set up a new theory to account for something that is not known to exist and is not likely to be established.

The only experiments yet published, in which efficiency is claimed to have been determined, are those of Dr. Jacques, who claimed an efficiency of about 32 per cent. But Dr. Jacques made no measurements of the temperature at which the heat was either received or rejected in the process. In fact, he claimed that there was no difference in temperature between the different parts of his apparatus—a claim that is manifestly absurd. From what is known of his experiments it is quite certain that the heat was received in his experiments at about 800° C. (absolute scale) and the temperature at which the heat was probably rejected did not exceed 300° C. The maximum efficiency of thermo-electric transformation would, therefore, have been about

$\frac{800-300}{800} = 62$ per cent., which leaves a considerable margin of possibility after allowing Dr. Jacques all he claims.

The difference T–t, which must be used in this calculation, is not, as has been popularly supposed, the difference of temperature between the hot electrolyte and the hot end of the inserted electrode, but the difference between the hottest and the coldest parts of the electric circuit, these being the points at which the heat is received and rejected if the action is thermo-electric.

Admitting, however, for the purpose of discussion that some other explanation is necessary than that of thermo-electric action, the theory of Mr. Steinmetz, which Dr. Kennelly seems to support, presents difficulties which are very great. It assumes that in a given system, comprising an electrolyte and terminal conductors, the energy of the system itself remains unchanged, while the system continuously absorbs heat at one point, converting it into static potential energy, and at another point this energy or its exact equivalent passes out of the system in a dynamic condition by a process which is necessarily both subsequent to and simultaneous with the process of storing (absorption). Inasmuch as the energy of the system, as a whole, remains constant, this process of subsequent and simultaneous change from a static to a dynamic condition, supposed to take place within the system, must necessarily be a theoretically perfect process having an efficiency of 100 per cent. Such a process seems to involve a contradiction of terms in its definition. Furthermore, this subsequent and simultaneous process explains nothing, except what is easily explained by thermo-electric action, according to which the heat would be absorbed directly by the circuit and simultaneously evolved as electrical energy without any intermediate process. Another objection is that if any such process exists, its very nature precludes the possibility of its being experimentally detected. Its existence could not even be proved by the indirect method of efficiency test suggested by Dr. Kennelly, since the efficiency of such a process could not exceed that of a heat engine.

The deposit of zinc on the copper, obtained in the experiment with zinc chloride, possesses certain peculiarities, from which I at first thought it might not be zinc, but an unknown *constituent* of zinc. The explanation offered by Dr. Kennelly that it is an alloy of zinc with the copper plate seems much more plausible, though an alloy of copper and zinc having the color of zinc and the chemical inactivity of copper is somewhat remarkable. The deposit is acted on only very slowly by acids, even when in contact with platinum foil.

Dr. Richards seems not to have understood that *Fig. 12* is merely *diagrammatic of the parts of the apparatus only* and is not intended to represent the apparatus in action nor its form. A thermo-electric apparatus, like a dynamo or galvanic battery, may properly be called such, whether it is in action or not. A dynamo standing idle may really be nothing but a mass of copper and iron, yet it is usual to call it a dynamo. It is to be understood, of course, that a thermo-electric apparatus in action requires the application of heat in such a manner as to produce unequal temperatures in different parts of the circuit.

The relevancy of Dr. Richards' remarks concerning the chemical reactions of the Jacques cell is not clear. The fact that carbon reduces sodium and most, if not all, metallic oxides at sufficiently high temperatures is generally accepted. It is well known, however, that such reactions do not evolve energy, except in the case of easily reducible metals, whose combustion heat is less than that of the carbon equivalent of the oxygen transferred. What does Dr. Richards mean by "*the surplus energy of the reaction supplying the motive power?*" What is this surplus energy and where does it come from? What chemical reaction takes place evolving any energy? The fact that metallic oxides having high formation heats are reducible by carbon only at correspondingly high temperatures is due to the fact that only at those temperatures can sufficient heat be absorbed to overcome the chemical affinity of the constituents of the compound and restore to them their original chemical energy. There is no surplus energy present, except the surplus heat of the furnace.

The formation heat of NaOH, like that of all other substances, is merely the heat given out or absorbed in bringing the substance formed in a reaction back to the initial temperature of the reagents. For the temperature of dissociation the formation heat of any compound is zero, and for any lower temperature it is the difference between the low temperature and the temperature of dissociation in degrees multiplied by the mean specific heat of the compound between those temperatures. The formation heat of any substance at a high temperature is always less than at a low temperature by the amount of external heat absorbed in passing from the low to the high temperature, and the determination of the formation heat at a high temperature would merely amount to the determination of the mean specific heat between the high and the low temperatures. Any electrical energy that could in any way be due to a diminution of the formation heat of NaOH at an elevated temperature would, therefore, be due solely to the external heat absorbed in raising and maintaining the temperature. The proper temperature at which the formation heat should be taken is the final temperature at which the heat is rejected when the body cools. In this case it is necessarily the temperature to which the electrolyte cools down after the source of external heat has been removed. In other words, the only energy that can originate in the system is that which it contains before any external heat is applied.

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*Stated Meeting, November 8, 1898.*

# THE STATUS OF ELECTRICAL INVENTION.

By William A. Rosenbaum.

The old saying that "There is nothing new under the sun," once found a firm believer in no less a personage than a member of the examining corps of the United States Patent Office. The gentleman referred to resigned his position for the reason, as given by himself, that he believed invention was about at an end, that in the then existing per-

fect state of mechanism and appliances nothing more was to be desired or attained and that the Patent Office would soon have to close its doors, whereupon he would be left without employment.

It is needless for me to say that this did not occur recently, for the march of progress is so rapid nowadays that the tendency is to predict more and greater discoveries rather than that mechanical and scientific progress has reached its limit. As a matter of fact, this prophecy was made before the invention of the sewing machine, the cotton gin, the type-writer, the perfecting printing press, and when the status of commercial electric invention was determined by the Voltaic battery and the simple telegraph. Curiously enough, the incident really marked the very threshold of the epoch in which all of our great electrical inventions were produced.

Since the beginning of this epoch, so rapid and effective has been the progress of electrical invention, that each branch of the science, from the moment of its inception, has been developed to a state closely approaching perfection, within a few years. In saying this, I do not mean to step into the shoes of the Patent Official and imply that there is no further room for improvement in the fields that have been entered, but rather that each branch of the science has had its pioneer inventions, followed quickly by the usual multitude of "improvements," interspersed here and there by controlling inventions, or "milestones," directing the lines of thought, and all subjected to the fining processes of the designer and engineer until, within a few years, sometimes less than a decade, the subjects have been given their definite character.

Notwithstanding the fact that the United States Patent Office is now issuing about twenty-five patents per week relating to electricity, it is noticeable that there are but few controlling inventions among them. Indeed, in the fields of telegraphy, telephony, electric lighting, electric railroading, chemical and mechanical generation and the storage of electrical energy, it is difficult to point to more than two or three controlling inventions of so recent origin as to be

within the last five years. And when we parallel this with the statistics showing the stupendous extent to which it has been possible for these subjects to interest capital, if we were not progressive, we might be prompted to believe that these branches of the science at least, have been perfected. The production of the commercial underground trolley furnishes an apt illustration of how invention in any art may come to a standstill, and even have its "rise and fall." Following the proposition to put the overhead trolley underground, came an avalanche of invention showing how not to do it.

Systems without number came out involving sections, sub-sections, relays, cut-outs, switches, sparkless contacts, methods of insulation, and so forth, the general object being to avoid leakage and render the line safe to persons and animals. But the futility of all this effort was suddenly demonstrated by the operation of one or two sub-trolley roads whose electrical construction was practically the same as that of the overhead system, to-wit: a bare live conductor supported upon insulators. In consequence, the avalanche of invention soon flattened out and gave way to the earliest and simplest ideas.

Naturally, the arts have been developed more rapidly in modern times than formerly. While the telegraph which originated in 1840, required about forty years, the telephone, which originated in 1876, only required about fifteen years in its development, and while it may be urged that telephony has not reached the same state of development as telegraphy, yet I think it lacks only a serviceable repeater to have acquired the same distinction.

Likewise, the dynamo-electric machine, which resulted from Faraday's experiment of 1831, and its converse the electric-motor, were of but little real value until half a century later, when the progress made in the theoretical treatment of magnetic problems made it possible to predict the electrical and mechanical output under given conditions of speed and load. Contrary to this, the two branches of the science, electric lighting and electric railroading, the two industries made possible by the dynamo and electric motor,

were developed, the former to a standstill, within fifteen years, and the latter within a decade.

In approaching more closely the subject of this paper, the writer may be permitted to say that some difficulty was experienced in determining on what plan the paper should be constructed in order that it might contain information of value. The subject refers to "invention" and not to engineering or commercial progress; it was, therefore, finally decided to take up the main branches of the art successively, and refer to those inventions in each which have been responsible for, or have directed the lines of, its development. It is believed that no systematic attempt in this direction has been made heretofore, and that a recitation of the inventions that have given shape to the art, with brief descriptions of each, may possibly prove to be of some interest and value.

Since the telegraph has the precedence in point of time among electrical devices affording commercially successful results, we naturally turn to it first. Up to twenty-five years ago the simple Morse system of telegraphy was the only one in general use. Experiments had been made with printing and chemical automatic systems, and although the duplex system was in limited use, it had not been perfected. As to the beginning of the art, the needle telegraph of England, I believe, has the precedence, but this was very shortly followed in 1840 by the more practical system of Henry and Morse, the electro-magnet of which is the responding element of the American telegraph system to the present day.

The key is one of the most important instruments of the system. A vast number of patents have been taken on it, the object of invention having been primarily to transform the old, heavy, cumbersome mass of brass introduced by Morse into the light "solid lever" keys used in this country at the present time, and of which the "Bunnell" key is the pioneer.

The relay, another important instrument, has undergone many changes in shape, dimensions and resistance since it was first invented. In weight alone, it has changed from about 300 pounds to 3 pounds. But improvements of both

this instrument and the sounder have been more the work of the designer than that of the inventor. The Morse register, which was formerly in use as the receiver, has been superseded by the present method of receiving by sound.

The first repeaters were known as the "button" repeaters; they were not automatic, since they required an operator in the repeating office to prevent interference. These were superseded by the automatic repeaters of Milliken, Horton, Weiny and a few others, in use to-day.

The "duplex" appeared first on paper, in 1858, and was not followed by anything more substantial till early in the seventies, when the well-known Stearns system appeared, which, with slight improvements, has remained the standard to the present time.

In the "quadruplex," since the work done by Mr. Edison in 1878, there have been few changes of consequence to record. With the substitution, however, of dynamo machines for batteries, to obtain quick acting increase and decrease of current on the quadruplex circuits for the operation of the distant relays, without affecting the resistance of the main line, the dynamo quadruplex key system was devised and is in use to-day by the Western Union Telegraph Company. In multiplex telegraphy the Delaney synchronous multiplex takes a prominent place, and is in use at the present time.

The need for rapid transmission brought out the automatic systems, in nearly all of which the message is first either punched, embossed, painted or chemically printed upon a strip of paper which is afterward fed into the transmitter. The chemical automatic systems have nearly all been superseded.

The writing telegraph is now being developed into commercial state. Its principle of operation is that of "compounding the movements of a point in two directions, the one at an angle to the other, the actual movement of the point being the resultant of the two movements."

Telegraphing from moving trains has been given some attention, the most successful system from a commercial standpoint being that which depends upon the laws of electromagnetic or electro-static induction.

The printing telegraph is largely in use for stock quotations and news. In general, such systems depend, primarily, for success upon the uniformity of rotation of a cylinder or wheel at a transmitting station, with a type wheel at a receiving station.

Long submarine telegraphy has not advanced with its increasing traffic, the difficulties in the way of high speeds having been only partially overcome. The Morse receiving apparatus, which was first tried with a speed of one or two words per minute, has been superseded by the Thompson, and later, on some lines, by the Cuttriss syphon recorders.

Much of the later work of telegraph engineers has been in the improvement of apparatus and the development of means for increasing the capacity of existing wires by the use of automatic and multiplex systems. The most recent and important result of this work is the synchronograph of Crehore and Squire, which bids fair to adequately meet any and all demands in the direction of rapid transmission for many years to come. A description of this system, even in brief, cannot be attempted here; suffice it to say that it has been practically used, and is capable of transmitting and receiving from 3,000 to 4,000 words per minute.

While formerly the telegraph was devoted to business and social use, it has now become an indispensable agent in the operation of fire, police, burglar and many other analogous systems, a detailed reference to which the limits of this paper will not permit.

Telegraphy through the medium of wires may, perhaps, be said to be fully developed. The best evidence of this is the fact that the field of "wireless" telegraphy has been entered and advances made well into the experimental stage. Telegraphing without wires over distances less than ten miles is an accomplished fact. The principle upon which this system is based may be described as follows:

At the transmitting station mechanism is provided for sending into space, whenever the signalling key is closed, regularly occurring electrical waves at a predetermined rate. These waves traverse the space intervening between the transmitter and receiver, are collected by the receiver

and sent through a metallic powder, the particles of which are in loose contact and normally offer such high resistance as to obstruct the flow of a battery current directed through it. The passage of the waves through the metallic powder causes its particles to cohere, and reduce the resistance sufficiently to permit the battery current to flow and operate a relay. Automatic devices are employed to loosen the powder particles the moment the sending key is opened.

The great inventions in telephony were made within the five or six years following the time when Alexander Graham Bell proved telephony to be a practical thing. The Centennial Exposition of 1876 was fortunate in at least two things —first, that it was held in Philadelphia; and second, that it made the first public exhibition in the United States of the articulating telephone.

The principle underlying the operation of the telephone, since its inception and to the present day, is best stated in that famous fifth claim of the fundamental Bell patent of 1876, to wit:

"The method of . . . transmitting vocal or other sounds telegraphically, . . . by causing electrical undulations, similar in form to the vibrations of the air accompanying the said vocal or other sounds. . ."

The multitude of devices that have been invented for transforming these air vibrations into "electrical undulations" may be divided into two classes: those in which a magnetic field of force is varied, and those in which the nature of mechanical contact between a plurality of conducting bodies, is varied.

The introduction of the telephone to commercial uses necessitated the supply of various auxiliary devices for calling and interconnection purposes, and the several thousand patents issued in the art attest to the vast amount of invention that has been necessary to bring it to its present degree of perfection. Brief reference to the most important of these will follow.

First of all came the Bell instrument used both as transmitter and receiver, and as in use to-day as a receiver only, is practically of the same construction as the original instru

ment, consisting merely of a magnet facing up a flexible disk forming or carrying the armature.

Following this very shortly, came the microphone or carbon transmitter, in which the movements of a diaphragm varied the pressure upon a body of carbon forming a part of the circuit. This instrument had many modifications involving carbon buttons, carbon pencils, balls and carbon powder, but no substantial changes have been made in late years.

The induction coil was the next important piece of apparatus. This made its appearance in 1877 and by virtue of it, it became possible to telephone to considerable distances with an initial current of low electromotive force. This device still plays its important part in all extended systems. The induction coil and the microphone transmitter brought into use the Voltaic battery in connection with telephony.

Various forms of calls have been invented and used, but the most acceptable and one of the earliest, is the magneto call by which the user generates the calling current. Allied to this is the automatic switch (1879), the function of which is to cut the calling magnets into circuit when the receiver is hung upon its supporting hook and to remove it from the circuit when the receiver is put into use.

We next come to the switch-board, an apparatus which has built up from the simplest beginnings to an extremely complex mechanism, in parallelism with the phenomenal growth of the telephone business.

The simplest instance of communication is a line with a single apparatus at each end. Following this came three or more instruments in series on one circuit with the consequent liability of interference, and a modification of this consisted in putting the instrument in parallel and using bridging bells. Then came the multiple circuit system with its multiplicity of wires and the objection of permitting conversations to be overheard. In all of these systems the person calling made his own connections. Next came central-station switch-boards. The simplest form is the single circuit board to which the wires from each instrument lead, and are there connected by an operator, as required. The

metallic circuit or "double wire" was the obvious modification of this. In small exchanges either the single or double circuit simple board presided over by one or two operators, is in use to-day, but for large cities where the exchanges accommodate a thousand or more subscribers, the single board was found to be inadequate and the invention of the multiple switch-board followed. As its name indicates, it is a plurality of single boards or sections, to and through each of which, every subscriber's line extends, with means on each section for establishing connection with the line of any other subscriber. Multiple boards are either single or double circuit.

In long distance telephony, the problems have been more for the engineer than the inventor. The apparatus differs only in details from that in use for short distances.

In the production of an efficient repeater, inventors have spent considerable effort without marked success. So soon as we shall have a satisfactory automatic repeater, telephony will have reached practically the same state of development as its sister art, telegraphy.

The fundamental inventions in electric lighting were practically all made prior to 1884, and what there is of interest subsequent to that time, to record, is mainly the work of the electrical engineer or skilled electro-mechanic. It is not expedient herein to give a history of electric lighting from its very beginnings; suffice it to say that during the seventy-five years following the discovery of the Voltaic arc, a number of hand and automatically regulating arc lamps were produced, and for the same period following the discovery that a continuous conductor could be brought to incandescence by passing a current through it, a variety of incandescent lamps were invented, even to involving the burning of carbon wires in an exhausted glass vessel. But the failure of any lamp in either class of lighting, to become a commercial success, was due as much to the lack of a sufficiently cheap source of current as to the inherent defects of the lamps themselves.

[*To be concluded.*]

# CHEMICAL SECTION.

*Stated Meeting, September 20, 1898.*

## HIGH EXPLOSIVES AND SMOKELESS POWDERS AND THEIR APPLICATIONS IN WARFARE.

BY HUDSON MAXIM.

[*Concluded from p. 386.*]

By the sacrifice of a little velocity, but still leaving us a velocity of 2,000 feet per second, we may make our aerial torpedo to weigh $1\frac{1}{2}$ tons, and to consist of 1 ton of steel, carrying a bursting charge of $\frac{1}{2}$ ton of high explosive. This projectile would be sufficiently strong to enable it to penetrate the deck armor of any battleship in the world before exploding, or to penetrate the belt armor of protected cruisers like the "New York" and explode inside the vessel. That such an explosion would be destructive in its effects I think all will be willing to grant.

The fuse to be employed is one of the chief features of the aerial torpedo. The question of fuse has always been one of the principal features of the problem of successfully throwing high explosives from ordnance Briefly, it is constructed in such a way as to absolutely preclude any danger of premature explosion in the gun, and when the projectile strikes the target, the action of the fuse is sufficiently delayed to permit the penetration of the projectile to a desired depth in earth or water, or to pass through light armor before exploding.

Let us now see what may be done with but a very slight change in present forms of ordnance and in present forms of shell. Let us take a gun of the same weight and cost as the present 12-inch, 52-ton, sea-coast rifle, and let us construct it to throw a projectile weighing 1,500 pounds, 1,000 pounds of steel and 500 pounds of high explosive. The caliber of the gun would be about 20 inches. The projectile thrown

would have a velocity considerably greater than the present 1,000 pound 12-inch shell, carrying a bursting charge of only 37 pounds of black powder.

Now, when we take into consideration the fact that it will not cost any more for a gun to throw aerial torpedoes, carrying bursting charges a hundred times as powerful as are now thrown, and without any sacrifice in velocity, but that we may even attain greater velocity, flatness of trajectory, and directness of fire than are now attained with high-power guns, and still throw enormous charges of high explosives, the value of this system ought to be apparent.

The system involves no radical departure from present forms of ordnance. The aerial torpedo involves nothing questionable or intricate in its construction, and no new or untried law, and, as has already been stated, there are several high explosives which may be thrown with perfect safety.

Lyddite, which is simply picric acid, is already employed by the British Government for filling shells for high-power guns, and this same material, either alone or admixed with other ingredients, has been long used by some of the Continental European powers.

In the *Westminster Gazette* of August 26th last, it is said that, "The reports to hand from the Soudan Expedition indicate that in the attack upon Omdurman great reliance will be placed upon the mischief-making power of the new lyddite shell. It is stated that when tried at Abu Sieh, Cairo, the effect of the time bursts were simply terrific, and it is asserted that the concussion of a burst can have effect 600 yards to the front and 300 yards to the rear."

What I propose is simply to throw larger quantities, but without subjecting the explosive to any greater shock in the gun than that to which it has been already subjected and been found to successfully withstand.

This should be borne in mind, that the same explosive that is now widely used for filling shells for high-power guns, may be used to fill aerial torpedoes, and that, in the aerial torpedoes, it will not be subjected to any more shock than that to which it is now subjected.

As already stated, it is the length of column of the explosive in the projectile that must be taken into account in considering the shock of acceleration upon it In the aerial torpedo proposed by me, the column of explosive would be subdivided by a strong cross partition, and no matter how large the shell may be in cross-section, the shock is no greater than as though it were but a few inches.

Naval and military authorities must soon give due consideration to the aerial torpedo. From $\frac{1}{2}$ a ton to 1 ton of high explosives can certainly be thrown with absolute safety and great accuracy at all fighting ranges at sea, and if such quantities of high explosive, striking and exploding on board a battleship by impact upon its superstructure, will destroy the vessel or throw it out of action, or if such quantities, when projected into the water, and exploding as submarine mines adjacent to the hull of a battleship, will suffice to blow her up or sink her, then the first shot of the aerial torpedo gun proposed by me will render obsolete every battleship in the world.

Immense sums of money will no longer be expended in armored protection which will not protect, and in the construction of huge and ponderous fighting machines whose very size renders them a more easy prey to the torpedo gun than a small and light cruiser, simply big enough to provide a portable and stable gun platform. If a projectile can be thrown which shall be sufficiently destructive to demolish anything and everything it hits, then, obviously, thereafter centralization of men and expense must be abandoned and men and weapons must be dispersed in order to form as many and as small targets as possible. Navies must fight in skirmishing order, exactly as armies on land now do.

If the battleship, forming a target ten times as great, offers no greater protection against the aerial torpedo than the small, unprotected cruiser, and costs ten times as much and carries ten times the number of men, it is certainly not more than one-tenth as efficient a fighting machine. Anything revolutionary in character, however meritorious, always has a hard fight for recognition, especially in overcoming the opposition backed by enormous vested interests.

It would be easier with a few cruisers armed with aerial torpedoes to make a scrap heap of every battleship of the combined navies of the world to-day, than it will be to even secure the system a place for once in the line of battle.

If there is even a fighting chance for the aerial torpedo to work the revolution in naval construction predicted, then this matter is a subject for serious consideration, especially by the United States Government, before making the enormous expenditures in battleships which Great Britain has made. Half a million dollars will build and arm a light torpedo cruiser which will carry one 24-inch torpedo gun and two torpedo mortars. This will demonstrate the efficiency of the system. If it fails, it costs but $500,000; if it succeeds, it will save $500,000,000. The battleship must go.

The great distance to which enormous quantities of high explosives may be thrown by torpedo guns and mortars and the hitting qualities of these weapons, when the enormous size of the target is taken into consideration within whose area a torpedo, striking, will destroy a warship, renders these weapons of supreme importance for coast defense.

Aerial torpedo guns, when once successfully tried, either on land or sea, will cause a revolution in coast fortifications as well as in war vessels. Aerial torpedoes penetrating deep into earthworks before exploding will be disastrous. It will then be the weapon rather than means of protection, that will be the dominating factor in both attack and defense. The cost by present methods, in ammunition and wear and tear of guns in bombarding coast fortifications or towns, is quite equal to the amount of damage done. This will all be changed by the introduction of aerial torpedoes.

The American fleet expended more than $2,000,000 worth of ammunition hurling shot and shell at the Santiago hills, and the damage wrought was quite insignificant, probably not more than 10 per cent. of what it cost the American Government in ammunition alone.

The "Vesuvius" threw a few shells carrying only 200 pounds of guncotton, and without any power whatever of penetration. Not much could be expected of these.

Suppose a few aerial torpedoes weighing a ton and a half, with a bursting charge of half a ton, and capable of penetrating deep into the fortifications before exploding, had been employed, would not the result have been vastly different? Would not enormously greater destruction have been wrought?

The lessons of the present war do not, as claimed by certain persons, teach us the uselessness of torpedo boats and of torpedo warfare, and nothing has been learned upon which to found any higher opinion of the battleship than we had before the war. The great lesson taught is the superiority of the American gunners and Americans as fighters.

Suppose, for example, that Cervera had had such a number of torpedo boat destroyers, of the Pluton and Furor type, as could have been constructed for what the American battleship "Oregon" cost—say twenty of them—and suppose those torpedo boats had been armed and equipped with American guns and ammunition, American torpedoes, and manned by Americans, and that they had sallied forth at night instead of in the daytime, and made a determined attack upon our fleet, is it not probable that they would have succeeded in destroying more of our war vessels than they themselves cost before they could have been destroyed?

Furthermore, suppose there had been mounted upon the Santiago hills, torpedo guns capable of throwing $\frac{1}{2}$ ton of high explosive over a radius of from 8 to 9 miles, might not the result have been different?

In these ante-millennium times, war is occasionally a necessary contingency, and when it comes we want the best tools we can get to fight with, and it is a crime for a nation not to be prepared for war, a crime against those who will be called upon to defend the country in time of war. It is a crime for a nation not to be abreast of the times in arms and equipments.

Improved guns and ammunition, improved methods for the employment of the most destructive agencies of offense and defense are but means of saving life. Modern armies and navies are but elaborate and efficient life-saving sys-

tems, and are as humanitarian in nature as the life-saving services along the coast of civilized countries, whose duty it is to warn vessels of danger and to succor those who may be cast away. The fort is as humanitarian in its nature as the lighthouse, and the seacoast gun as much an implement of mercy as the gun that throws the life-line to a stranded wreck.

The cost to this country of the present war with Spain, above what it would have been had the country been prepared for war, is difficult even of approximation—prepared in every sense, as well as with armaments.

It is doubtful if there would have been any war had not Spain been encouraged by her belief in our weakness or unpreparedness, for it was not only generally believed in Spain, but by many in other European countries, that Spain would at first have the best of the fight. The world has been taught a lesson by a reminder of the fighting qualities of the American character. We have also been taught a lesson which the country ought not soon to forget—the necessity of being prepared for war.

The country which finds itself involved in war in a state of unpreparedness, can make good deficiencies in such respects only at the cost of great sacrifice of life.

* * * * * * * * * *

War must be looked upon as a business, and subject, like any other business, to business principles. War is the business of destruction of life and property of an enemy, and has no regard for the sacredness or pricelessness of human life. Lives become part of the paraphernalia of war, and lives and property become representative in value. The art of war consists in the employment of means and instruments to accomplish the desired purpose with the minimum of risk, expenditure and loss on the investment.

The history of nations is the history of wars. The millennium of secure universal peace is yet far off. There will be need of guns just so long as one man, through eyes of injustice, sees any use for another man's property, or until all nations shall unite in a common federation, a universal

family of mankind, bound to peace under laws made in the common interest, when shall be realized that ideal society mentioned by Tennyson:

> "The parliament of man, the federation of the world."

At best, war is cruelty, but it is not only often a necessity, but unavoidable, and once engaged in should be made as terrible and destructive as possible while it lasts, in order that it may be brief as possible, thus minimizing the evil in the aggregate.

Not only do swords and bayonets, guns and gunpowder, torpedoes and high explosives constitute the weapons of war to-day, but the steamboat, railroad, telegraph, the woollen and the cotton mill stand on the plane with the rest; the chemist, electrician, engineer and inventor, find duty as serviceable to their country as does the bleeding soldier; and all the vast industries of a great commonwealth unite with its husbandry to supply the sinews of war. By just division of labor, the ploughman, artisan, scientist and inventor strike as nobly for their country and render her equal service as though they were to fight and bleed and die upon the field of battle.

One man, with a Maxim-gun, is worth more in a fight to-day than would be 100 men armed with the old-fashioned muzzle-loading rifles used as late as the American Civil War. The new magazine rifle makes a single soldier more than a match for a dozen men armed with the old weapons. A troop of artillerists operating modern quick-firing guns, with shrapnel and canister, could stand against ten times their number armed with the old smooth-bore muzzle-loading field guns. What does this mean? It means that only one-tenth as many men need be sent away to war, while the remaining nine-tenths may stay at home.

It may be argued that an enemy would be equally well equipped. Very true. But his equipments and the home industries producing them demand of him also that the nine men work and only the tenth man fights.

There can be but one interpretation as to the results upon civilization of improvements in implements of war,

and it is that more will be done by money and machinery and less fighting done by hand, permitting and demanding that large numbers remain at home engaged in industrial pursuits, while the home is defended less by blood and more by the fruits of industry.

The most deadly and destructive implements of war are the most humane, and the producers of them may justly be looked upon as humanitarians. The best guaranty of peace is to be in a position to make a breach of it as undesirable as possible to an enemy. The greatest security against receiving heavy blows is to be in a position to strike them. Peace is made most secure by being prepared for war, by pushing to the highest state of development possible the weapons and means of offence.

The inventors of deadly engines of war place in the hands of scientific and enlightened nations the means of controlling wars. Such inventions have put a limit to the time when barbarian hordes can overrun and subdue the earth, to ravage, destroy and enslave by sheer brute force and power of numbers.

## CHIMNEYS FOR INCANDESCENT GAS LAMPS.

By Ernest M. White.

In the year 1880 or thereabouts, Carl Auer, a student of chemistry at Heidelberg became interested in the subject of gas lighting. Believing in the incandescent principle, he directed his experiments, research and study, along the lines of that system; producing, eventually, the Auer or Welsbach incandescent gas lamp, which has recently revolutionized the Science of Gas Lighting.

Following closely, some years ago, the evolution of the incandescent gas lamps and the improvements made in it by Auer and other inventors through whose hands it had passed, I found that no real improvements had been made in the chimney. This is by no means an unimportant ele

ment of the lamp, its function being partly to protect the mantle from injury, and partly to create draft sufficient to supply to the mantle the oxygen necessary for the combustion of the gas.

Recognizing the defects in the Argand chimney used on the incandescent gas lamps and believing it possible to overcome them and to use the mantles after they had become broken or torn, I began a series of experiments with the narrow cylindrical chimney in general use and all the other forms that came to my notice, some of which I shall show and explain, together with one invented by myself,

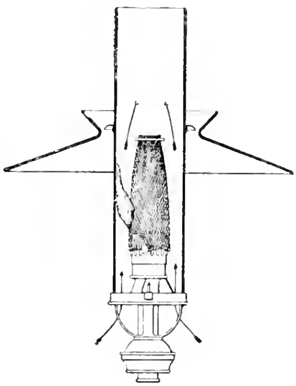

FIG. 1.

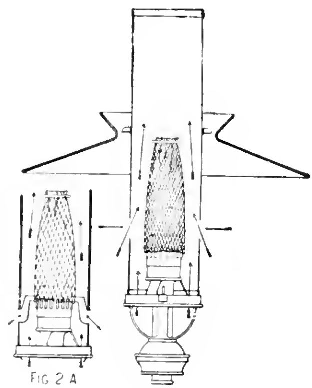


FIG. 2.

which is constructed upon a new principle in incandescent gas lamp chimneys.

*Fig. 1* shows the single draft narrow cylindrical, or Argand type of chimney, the best known perhaps of all those used on the incandescent gas lamps. These are made of glass or mica, and, in order to obtain sufficient draft are made of small diameter, about 2 inches. Owing to the close proximity of these to the mantle, as soon as that delicate fabric has become torn, they are almost invariably cracked by the flames inpinging upon the inner walls and in breaking they usually carry with them the mantle. At times, however, such glass chimneys do not break until hours after the light has been turned out. I know of one case in which breakage

occurred some weeks after the chimney had been taken off the lamp.

*Fig. 2* is a narrow chimney known as the "Tweer," in which I have placed near the bottom a number of small holes. The air entering these openings, mixes with the ascending column of air, bringing oxygen constantly in contact with the mantle, rendering combustion more nearly perfect, and the mantle incandescent to the very top, producing a more brilliant light.

*Fig. 2 A* is a blower placed beneath the narrow glass chimney and intended to improve combustion.

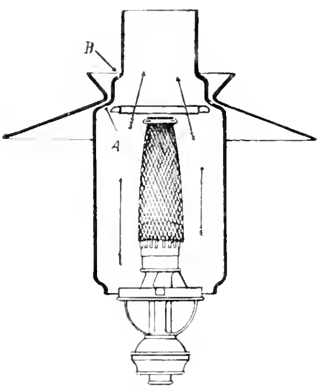

Fig. 3.

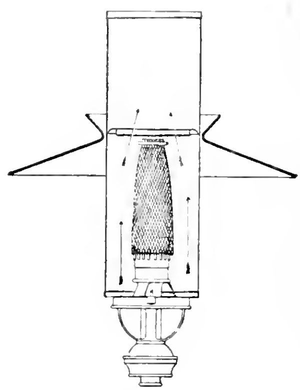
Fig. 4.

*Fig. 3* shows an attempt to overcome the breakage of the chimneys and to use broken or torn mantles. It has all the faults of the narrow chimney, and, owing to the sluggish single draft through it, the combustion is imperfect and the light obtained about 25 per cent. less than that obtained with the narrow chimney. Furthermore, the conformation of the top of this device is such, that, by the unequal expansion it is frequently broken at the shoulders *A* and *B*, the moment the flames come in contact with it. When this occurs, the shade which is supported by it usually falls with it and is also destroyed.

*Fig. 4* represents a wide single-draft chimney about $2\frac{5}{8}$ inches in diameter and made of mica, designed evidently to

correct the faults of the foregoing globe and the narrow chimney. The light with this chimney is remarkable sensitive to air currents and is very inferior to that produced with the narrow chimney.

*Fig. 5* shows a combination of a large globe and a metal top, which serves as a shade. This had its origin in the mind of Mr. Arthur Paget, an English inventor. It is undoubtedly, in many respects, superior to the foregoing devices. Like these, however, except when the gas pressure is very high, the light it affords is much below that produced with the narrow chimney, and in appearance it is not at all pleasing to the eye.

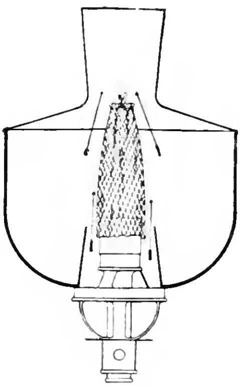

FIG. 5.

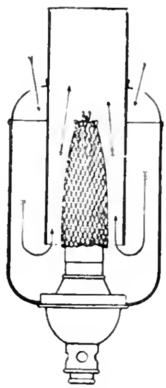

FIG. 6.

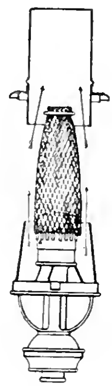

FIG. 7.

*Fig. 6*, Mr. Daniel Macfie, another English inventor, has devised this form of chimney. Practically, this is the narrow chimney surrounded by a large globe closed at the bottom. The principal function of this enclosure seems to be to render the light more insensible to air currents, and to prevent the chimney flying about when it breaks.

*Fig. 7*, like the foregoing devices, had its origin in England, and is a two-part chimney. One part is above and the other surrounds the lower part of the mantle. Some few improvements in the details of this device are found in U. S. Patents granted to Marsh. It is used somewhat in lamps for street lighting. In candle-power the light does not equal the Argand chimney.

*Fig. 8* is a modification of that shown by *Fig. 7*, and forms part of patents granted to E. M. White. This is not a forced draft chimney, but a ventilated globe. The light produced with this device while not equal to that of the narrow chimney, is better than that obtained with any of the previously shown devices intended to use damaged mantles. The breakage of the glass is rather high.

*Fig. 9* represents the outline of a chimney devised by myself and which is constructed upon the ejector, or automatically forced-draft system. This involves a new principle in incandescent gas lamp chimneys, and is intended to

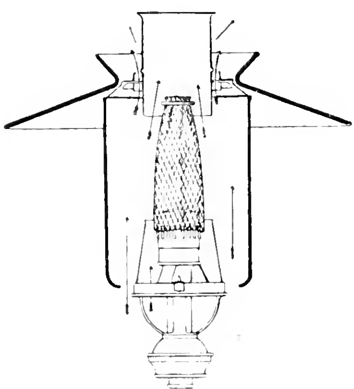

Fig. 8.

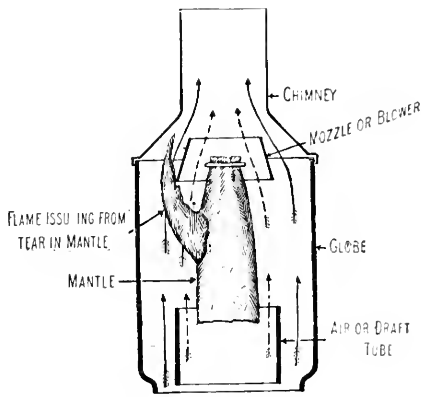


Fig. 9.

use damaged mantles, to overcome the destruction of chimneys and to render the light less sensitive to air currents.

This device, which dispenses entirely with the very troublesome narrow chimney, consists, essentially of a globe about 3½ inches in diameter, which forms a combustion chamber, an air-tube surrounding the lower part of the mantle to separate and to direct the drafts, and an ejector or jet blower which is made of metal and placed immediately above the mantle.

In this chimney, the rapidly ascending column of the products of combustion (called the central draft and indicated by dotted arrows) enters the blower or ejector nozzle, where it acts the same as steam in an ejector, inducing an

outer draft, which, moving upwards close to the inner walls of the globe, forces away from the glass and into the metal chimney the flames issuing from holes or rents in the mantle, thus reducing the breakage of the glass to the lowest limit, and uniting with the central draft above the blower, emerges through a chimney common to both.

It has been demonstrated with this chimney that the light obtained is equal to that produced with the Argand type, is clearer and diffuses better, and with broken and torn mantles is frequently brighter than it is possible to obtain with mantles in perfect condition. It has also been found

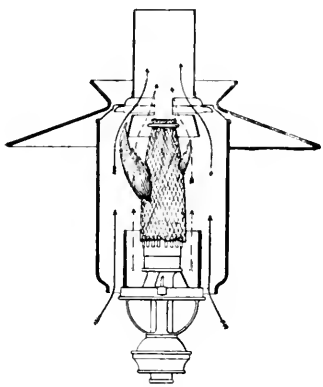

FIG. 10.

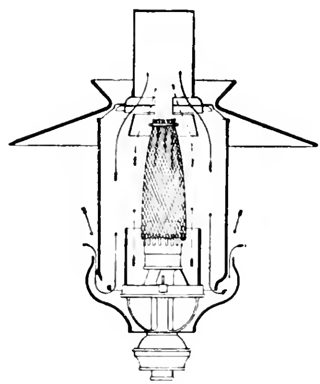

FIG. 11.

with it that mantles that are broken, torn and apparently worthless can be used as long as there is a shred left, and that their useful life is increased from three to five times. The breakage of glass is reduced to the lowest possible limit, and, furthermore, the globes do not need the frequent cleaning necessary in the case of the narrow type.

*Fig. 10* shows the way the chimneys are applied to the Welsbach light and how the flames are forced away from the glass.

*Fig. 11* illustrates this chimney, with a draft guard, intended for use in halls, corridors, etc.

This system of chimney seems to be the most economical, efficient and practical chimney yet produced for the

incandescent gas lamp. With its aid the users of this most excellent light are enabled to realize all of the saving in gas that it is possible to effect by the use of the incandescent system, without being obliged to spend this saving and often more for new mantles and chimneys.

## IN MEMORIAM.

### G. MORGAN ELDRIDGE.

In the death of G. Morgan Eldridge, which occurred most unexpectedly on October 20th, the Franklin Institute, and more especially its Committee on Science and the Arts, has suffered the loss of one of its oldest and most useful members, and it is eminently proper that the Committee should testify, by its official action, its appreciation of his zealous and honorable service, continued constantly through many years.

Mr. Eldridge was the eldest son of Griffith M. Eldridge, for many years a prominent merchant of Philadelphia.

He was born in Philadelphia on January 3, 1831, and at the time of his death was in his 68th year. He traced his ancestry on both paternal and maternal sides to the earliest colonists of America. In 1838, his family removed to Cecil County, Md., where his early life was passed, and where he was fortunate in having as schoolmaster, Squire Hayes, a man of unusual ability for that position, and who filled, as well, the offices of Magistrate and General Surveyor until his death.

Mr. Eldridge was sent to Nazareth Moravian School to complete his studies, the foundation of which had been so well laid that even at this time he was accustomed to work out and plot the surveys which he had assisted his instructor to make.

Having concluded the course of study at Nazareth, he was for a time employed on the staff of Dr. James Higgins, Agricultural Chemist of the State of Maryland, after which

he entered the law office of the late Samuel H. Perkins, of the Philadelphia Bar, and was admitted to practice in 1853.

His natural fondness and aptitude for mechanics caused him, early in his professional career, to turn his attention to the practice of patent law, to which he remained devoted. His interest in scientific subjects soon attracted him to the Franklin Institute, with which he became connected as a member in 1874. He was elected a member of the Board of Managers in 1885, and served in that capacity until 1890.

Mr. Eldridge's special interest in the Institute, however, was centered in its Committee on Science and the Arts. He was enrolled as a member of this body when it was still a voluntary organization. When it was reorganized and made an elective body, he was largely instrumental in drafting the very efficient revised rules and regulations under which the Committee is at present operating. He was made one of the original members of the reorganized committee, and was continued in his membership by successive elections, to the time of his death.

Of the usefulness of his long and constant services to the Committee, his colleagues only can form a just estimate, and it must suffice here to record the fact that he earned the fullest measure of their esteem and gratitude.

## NOTES AND COMMENTS.

### ADVANTAGES OF MECHANICAL DRAUGHT OVER CHIMNEYS FOR BOILER FURNACES.

Mr. Walter B. Snow, at the recent meeting of the Northwestern Electric Association strongly advocated the substitution of mechanical draught in place of chimney draught for furnaces. This can be accomplished either (1) by forcing the air into a closed ash pit, and maintaining therein a pressure in excess of the atmosphere ; or (2) by exhausting the air and gases from the flue or uptake, and thereby creating a partial vacuum which will cause a constant onward flow of air to the combustion chamber. The first method is designated as "forced draught" and the latter as "induced draught." In both types of mechanical draught centrifugal fans are used to render the draught conditions positive at all times.

The advantages of mechanical draught as stated by the author are its posi-

tiveness and flexibility. Its positive character renders its action independent of the weather; and its flexibility lends to it that characteristic so lacking in the chimney, the capability of exactly adapting the intensity of the draught as well as the volume of air to the requirements of the instant. Especially is this advantage noteworthy in cases where the service is irregular in character, that is, when the demand for steam is fluctuating, as, for example, in traction service where they are often sudden and immense.

Again, a convenient feature of mechanical draught, pointed out by the author, consists in the ability to burn cheap fuels, which are almost invariably of small size and require an intensity of draught which is not readily created by means of a chimney.

Also, the positiveness and intensity of the draught produced by a fan makes it a valuable aid in connection with the suppression of smoke—a question that is of the first importance in cities where soft coal is the only fuel used.

Turning to the economic side of the question, the author points out that the chimney is an absurdly inefficient means of creating an air movement, affirming that it can readily be shown that under the ordinary conditions of steam boiler practice a fan will remove a given amount of air with the expenditure of only one seventy-fifth of the cost required by the chimney. Other economic advantages are itemized, but need not be specially referred to The concluding portion of the paper contains a valuable statement of the comparative cost of the two systems, which should receive the careful attention of steam users. This is accordingly quoted:

"In order that a definite comparison may be made between the two methods of draught production, a certain 1,600 horse-power plant has been taken, of which the cost is known. This consists of eight modern water tube boilers, two economizers, and a chimney 8 feet in diameter by 180 feet high. The latter is located just outside the boiler house wall. If a duplex induced mechanical draught apparatus, each fan capable of operating the entire plant, should be substituted for the chimney, it could be placed immediately above the economizers, and with its attached engines could be rigidly supported by beams resting on the economizer walls. A short stack would serve to discharge the gases above the roof.

"The cost of the chimney, with damper regulator and dampers, is \$9,300; that of the fans, engines, draught regulation and short stack, installed complete, would be about \$3,500, or only 38 per cent. of the draught-producing apparatus for which it is substituted. That is, the saving would be \$5,800.

"With the increased draught produced by the fans it would be possible to raise the combustion rate and the steaming capacity, or, what is equivalent, the same capacity might be maintained with a less number of boilers Suppose one of the eight boilers be omitted from the original design, making the plant 1,400 nominal horse-power. A further saving of about \$4,000 may thus be secured.

"If the land be valuable the reduction of space incident to the employment of mechanical draught may have an appreciable effect. If worth, say, \$2 per square foot, the saving by omission of chimney and one boiler would be about \$2,000. The total saving in first cost resulting from an expenditure of \$3,500 for mechanical draught may thus be shown to be \$11,800; that is, the saving is nearly three and one-half times the expenditure necessary to

secure it. Obviously there is a coincident reduction in the fixed charges for interest and taxes.

"The power expenditure for operating the fans should be practically appreciable in any well-designed plant in which provision is made to utilize the exhaust steam from the fan engine.

"The most direct saving in operating expense which may be secured by the introduction of mechanical draught is that resulting from the utilization of cheaper fuel. Such a plant as previously described would, under good conditions, probably require at least 8,000 tons of high grade coal per year, operating ten hours per day. If a saving of only 25 cents per ton could be effected it would represent an aggregate of $2,000 per year, a very good return on an investment of $3,500. But in many cases much greater savings may be brought about. A case in point is that of the United States Cotton Company, Central Falls, R. I., where, with a 1,000 horse-power boiler plant, the fuel originally employed with chimney draught was George's Creek, Cumberland, costing (at that time) $4 per ton. With forced draught a mixture of No. 2 buckwheat screenings and Cumberland is now used, costing $2.62 per ton. The saving has been about $125 per week, enough to pay for the special steam fan in about six weeks.

"Other direct and indirect advantages of mechanical draught might be presented, but the limits of the paper will not permit. If it were not for its rough-and-ready character the chimney would long ago have been discarded, because of its wastefulness. In the search for the highest efficiency such waste can no longer be ignored, and when dollars and cents are concerned, crude methods must give way to those of greater refinement. It is for this reason that the most progressive engineers of the present day are not only considering but adopting mechanical draught as a substitute for the chimney."

W.

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## POSSIBLE IMPROVEMENTS IN THE MANUFACTURE OF ALUMINUM.

*London Engineering* lately published a valuable summary of the present state of the aluminum industry, which contained an instructive analysis of the several items of cost in the manufacture, given on the authority of Professor Roberts-Austen, chemist to the British Mint. From this it appears that the current selling price of the metal is 33·2 cents per pound. The cost of production is estimated to be 27·2 cents per pound, of which only 2·2 cents is for electric energy consumed in its production, while the co t of the raw material is placed at 12 cents.

It is hopeless to expect any further reduction in the cost for power, which as appears from foregoing figures is extremely low. There is room, however, for considerably lessening the cost of the raw material used in the manufacture, and in this direction rather than in the invention of radically new methods of manufacture, there is reasonable prospect that a cheapening of nearly one-third in the present cost of production may be realized.

Becker, the former manager of the works of the Societé Industrielle d' Aluminum at St. Michel in France, to accomplish this object, proposes to substitute calcined beauxite, costing about 1 cent per pound, for the refined alumina generally used. Since 2·2 pounds of this calcined beauxite would

suffice to produce 1 pound of aluminum, it will be manifest, from the figures given in what has gone before, that this substitution would reduce the cost of aluminum by nearly 10 cents per pound.

The drawback to this suggestion, however, is the fact that the metal thus produced would contain considerable (perhaps 6 per cent.) of silicon and iron as impurities, and some cheap method would have to be devised to refine it. This is by no means an easy task, but is, nevertheless, within the range of practicability. This proposition is one which should appeal strongly to inventive metallurgists, since even the saving of a few cents per pound on the present cost of producing aluminum would be of immense importance to the industry. W.

## USE OF ALUMINUM FOR ELECTRIC CONDUCTORS.

At one of the electrical installations at Niagara Falls, the plan has been adopted of using aluminum in place of copper for the conductors, connecting the dynamos at the bottom of the shaft with the plant at the top of the cliff. The *Western Electrician* gives the following details:

"The bars used are 25 feet in length, 6 inches wide and ½ inch thick, four being used in parallel; every 25 feet they are bolted and riveted together; at the top they are connected with aluminum cables 1¼ inches in diameter and covered with rubber insulation; the ends are set into sockets into which melted tin is poured. The total weight of these aluminum conductors is about 22,000 pounds, while the same work would require 48,000 pounds of copper." W.

## AN IMPROVED ICE BOAT.

There has lately been turned out from one of the English shipyards a vessel designed as an ice-breaker, which embodies a novelty in construction that may add greatly to the efficiency of vessels designed for this service; the details of this construction are given herewith. One propeller is arranged aft, in the usual position, and another smaller propeller forward. The forward propeller, by giving to the water under the ice a high sternward velocity, deprives the ice of its support and reduces its resistance to crushing, so that the advancing bow of the vessel, which is arranged with a suitable overhang, cuts its way into the unsupported ice without experiencing either the shock or resistance to which former types of ice-breakers were constantly exposed. The vessel is of the following dimensions: Length, 202 feet; breadth, 43 feet; depth, 21 feet 9 inches. She will be fitted with two sets of triple expansion machinery of special construction. The vessel has been constructed for the Imperial Senate of Finland, and will be principally used in keeping the port of Hango open during the winter. W.

## OBSERVATIONS ON AUTOMOBILE VEHICLES.

One of the recent meetings of the Austrian Society of Engineers and Architects was devoted to the discussion of the present state of the automobile vehicle.

On the subject of motive power, there were considered steam, the various forms of internal-combustion motors—using petroleum, benzine, acetylene and similar substances—and electricity. Steam does not appear to play a notable part in connection with the development of this new means of transportation. The internal-combustion engines appear to have met with most general favor on the continent; while the electric-storage battery—which undoubtedly offers the most desirable and elegant solution of the motive power problem—has received the most attention, and most satisfactory application in England and America.

The transmission of the motive power to the point of application was considered the most difficult problem in connection with the design of automobiles. The mechanism required for this function differs materially for the different kinds of motors. The benzine motor, for example, runs at a constant speed of about 700 revolutions per minute, which must be reduced to between 25 and 100 revolutions on the driving wheels. Electric motors, while more readily controllable, still require considerable reduction. Steam, in this respect, has advantages over both the preceding types, but the objections to this medium for automobile service on other accounts are serious.

It was pointed out that many of the constructive details of motor vehicles have been adapted from the bicycle, the wheels, ball-bearings, pneumatic tires, etc., having been copied without change, except in dimensions. To this adaptation there can be no criticism.

Other portions of the design of automobiles, especially those supplied by the carriage builder, come in for severe criticism. In this category were placed the heavy leather work, dashboards and other details, very appropriate for horse propulsion, but quite incongruous when applied to the new service. It was concluded that motor vehicles have come to stay (figuratively speaking), but that there is still great room for improvement in their design and construction.

W.

## A POSSIBLE NEW METALLIC ELEMENT.

In a memoir lately presented to the French Academy, reference was made to a new radio-active substance present in pitch-blende, and which the authors believe to be due to the presence of a new element. It is said to have a much more pronounced effect than uranium, as described by Becquerel. They propose for it the name "polonium," indicating the country from which the mineral was obtained.

W.

## FUNGI AS A SUBSTITUTE FOR YEAST IN FERMENTATION.

It was reported at the recent meeting of the International Chemists' Congress, held at Vienna, that Dr. Calmette, Director of the Pasteur Institute in Lille, had succeeded in cultivating a fungus which entirely replaces yeast for fermentation. The following details have been published:

"Trials on a large scale have proved the enormous advantage afforded by the use of these cultivated fungi in the place of yeast. In the case of maize, brought to fermentation by means of the fungi, a much larger quantity and better quality of alcohol are obtained at considerably lower cost, the spirit

being cleaner and containing less empyreuma as a consequence of the absence of the microbes found in yeast. A ton of corn requires but a few grains of the fungi for purposes of fermentation. Dr. Calmette has further proved that this aseptic method of fermentation works with equal success in the factory and in the laboratory, whether employed on a large or a small scale, not one malignant microbe having been found in thousands of gallons." W.

## A CELLULOID COMPOSITION FOR DRIVING BELTS FOR MACHINERY.

An English inventor has patented an improved belt material for power transmission which consists in using a suitable textile fabric as the basis, and impregnating this thoroughly—so that saturation takes place—with celluloid applied as a thin solution. The material is treated in this way in large webs or sheets, which is then cut up into strips of the required width and length. Several strips may be cemented together to secure a stronger belt, or a strip similarly impregnated with celluloid is used to envelop the other, which then forms a central core. By this process the belt is said to maintain its flexibility, while the celluloid, being incorporated into the texture of the fibers, gives the belt great strength, prevents stretching and renders it entirely waterproof. This last-named property is of much importance in many situations where the nature of the work forbids the use of cotton or leather. W.

## MERCERIZED COTTON AND VISCOSE.

In the Zeitschrift fuer Angewandte Chemie there has lately appeared an interesting summary of the present state of the industrial applications of mercerized cotton of which the following is an abstract:

The origin of this new branch of industry is due to John Mercer, in England, in 1852. The original invention (treating cotton fiber with caustic) was lost sight of until it was revived by Depoullij in 1884, in one of the Alsatian cotton mills, to produce an imitation of crepe. A further extension of the invention was made by Messrs. Thomas and Prevost, who employed the process with the fiber under tension for the purpose of producing a silky luster on cotton. Thus far, however, the process has received only a limited application, although its use is extending. Recently Messrs. Cross, Bevan & Beadle, in England, by treating Mercer's alkali-cellulose with carbon bi-sulphide obtained a mass soluble in water which, because of its great viscosity, they called "viscose," and which they determined to be a solution of sodium cellulose xanthate. By several methods—such as spontaneous coagulation, heating, treatment with acids and such—the cellulose originally employed was found to be separated, though not in its fibrous condition, but as a plastic, translucent mass.

This "viscose" finds application in cotton printing and sizing, as a fixing material for pigments. It is also said to afford a substitute for celluloid, for sizing paper and for the production of numerous articles of ornament, such as are generally made from ivory, bone, horn, etc. W.

# Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, November 16, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, November 16, 1898.

MR. H. R. HEYL, in the chair.

Present, 126 members and visitors.

Additions to membership since last report, 13.

The Secretary reported a vacancy in the Committee on Science and the Arts, caused by the death of Mr. G. Morgan Eldridge.

Mr. J. J. De Kinder was elected to fill the unexpired term of the deceased member.

Mr. George D. Burton, of Boston, presented a communication describing an electrical process of his invention for unhairing and tanning skins, illustrating the subject with the aid of a number of lantern slides, and an electrolytic bath, in which the unhairing of a number of kangaroo hides was experimentally shown.

The process consists substantially in subjecting the skins, for unhairing, to an aqueous bath containing unslaked lime and a small addition of arsenic tersulphide, and passing an electric current through this bath with the aid of suitable electrodes. The internal arrangement of the bath and the manner of disposing the hides therein may be modified in various ways. The tanning process is substantially similar to the unhairing process, except that the desired tanning agent is introduced into the bath.

The inventor claims that the processes of unhairing and tanning are very materially facilitated by the use of the electric current in the manner just described, the operations being completed in a fraction of the time ordinarily required.

The subject was discussed by Dr. Goldschmidt, Dr. Wahl and the author. The inventions were referred to the Committee on Science and the Arts for investigation and report.

Dr. Chas. J. Hexamer read a paper describing his method for fire-proofing wood, with especial reference to rendering the woodwork of warships incombustible. After reviewing briefly the state of the art, the speaker gave an account of a series of experiments which he had made for the purpose. He had obtained the best results by the suitable injection into the wood of water-glass solution followed by a solution of sal-ammoniac, by which a deposit of silica was effected within the pores of the wood. The details of the operation were briefly described, and are reserved for publication.

The subject was referred to the Committee on Science and the Arts.

Mr. Wm. McDevitt, Inspector of the Philadelphia Board of Fire Underwriters, made some remarks on the inflammable and explosive properties of

smoke and their influences in causing the spread of fire. The speaker illustrated his remarks experimentally in a most instructive manner, with the aid of a model building.

The subject was discussed by Drs. Hexamer, Goldschmidt and the speaker.

Adjourned. WM. H. WAHL, *Secretary.*

## COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, November 2, 1898.*]

Reports on the following subjects were considered:

Passed first reading :

*An Inertia Indicator.* Wilfred Lewis, Philadelphia, Pa.

The following reports were adopted :

*Improvements in Pneumatic Dispatch Tube Apparatus.* B. C. Batcheller, Philadelphia.

ABSTRACT.—For a complete description of the Batcheller system, the reader is referred to the JOURNAL for August, 1898, *Art.* "Recent progress in the development of pneumatic dispatch tubes, by B. C. Batcheller."

The report finds that although a large number of patents have been granted to various inventors looking to the use of pneumatic tubes of sufficient size for the transmission of mail matter and parcels, the Batcheller patents were the first to form a complete system of practical value for larger tubes, in proof of which the report cites the successful application of this system to the 6- and 8-inch pneumatic dispatch tubes now in practical operation in Philadelphia, New York and Boston. The system is protected by a series of patents of the United States, granted to B. C. Batcheller.

For the skill with which the engineering details of the system have been worked out, and the ingenuity displayed in adapting the elements used in the inventions to their respective purposes, the award of the Scott premium and medal is recommended. [*Sub-Committee.*—A. Falkenau, Chairman ; John M. Hartman, C. J. Reed.]

*Chimneys for Incandescent Gas Burners.* Ernest M. White, Philadelphia.

ABSTRACT.—For a full description, with illustrations of these improvements, the reader is referred to page 464 of this impression of the *Journal.* The invention is patented to applicant (see U. S. patent No. 589,323, August 31, 1897).

The report finds the White chimney to be an improvement over the narrow cylindrical chimney in common use. Being larger in diameter than the ordinary chimney, it allows an incandescent mantle that is worn or damaged to

be used for a greater length of time than would be possible with the ordinary straight chimney, the greater width of the chimney preventing the flame that extends through the rent from striking against and thus breaking the glass. The report finds that the applicant's claim, "that the illuminating power is increased over the ordinary chimney," is sustained only in the case of a broken mantle, "with which the illuminating power is slightly greater than with a perfect mantle, using either the cylindrical or the White chimney." A certificate of merit is awarded. [*Sub-Committee.*—Frank P. Brown, Charles A. Hexamer.]

*A Method for the Rectification of the Circumference.* Charles Morrell, Chicago, Ill.

ABSTRACT.—This method "is an attempt to effect, by means of ruler and compass, a construction which will yield a straight line equal in length to the quadrant of the circumference of a given circle, an undertaking necessarily foredoomed to failure." (The author's construction cannot be made intelligible without the aid of an illustration.)

The report finds that the method proposed by applicant gives a correct result only in case "$\pi = \sqrt{10}$, or, 3·162, a value too great by about two-thirds of 1 per cent." [*Sub-Committee.*—Edgar Marburg, Edwin S. Crawley.]

*A Method for the Quadrature of the Circle.* Charles Morrell, Chicago, Ill.

"The general observations introducing the preceding report are equally pertinent to the present subject. The quadrature of the circle, whether by the construction of a square equal in area to a given circle, or, as in the present case, by the construction of several elementary figures whose individual areas may all be expressed—as is here wrongly claimed—in terms of the powers and roots of rational numbers, is an attempt at performing that which, in an exact mathematical sense, is impossible." (The author's construction requires illustration to be intelligible.)

Applicant's construction, the report finds, on analysis, gives the correct result only if $\pi = 6 - 2\sqrt{2}$, or, 3·172; a value too great by about 1 per cent. [*Sub-Committee.*—Edgar Marburg, Edwin S. Crawley.] W.

## SECTIONS.

CHEMICAL SECTION.—*Stated Meeting*, Tuesday, November 15, 1898. Dr. Wahl, Chairman *pro tem.*

Dr. Harvey W. Wiley, chemist to the Department of Agriculture, Washington, D. C., made an address on "The Agricultural Possibilities of Our New Possessions." The speaker confined his remarks chiefly to the Hawaiian Islands, with incidental reference to the West Indian islands. The subject was well illustrated with lantern views.

The meeting passed a vote of thanks to the speaker for his instructive and

interesting remarks. The communication will appear in abstract in the *Journal.* W.

ELECTRICAL SECTION.—*Special Meeting*, Tuesday, November 8, 1898. Mr. Carl Hering in the chair. Mr. Wm. A. Rosenbaum, of New York, read a paper on "The Status of Electrical Invention," which was referred for publication. Mr. J. H. Cork described the Jenkins' improved lamp holder, for electric incandescent lamps. This invention affords a convenient means for automatically attaching an incandescent lamp firmly to iron work of any kind, in positions where light is desired, and which are difficult of access.

*Stated Meeting*, Tuesday, November 22, 1898. President W. E. Harrington in the chair.

Mr. A. J. Wurts, Pittsburgh, Pa., presented a paper, illustrated elaborately with experiments, on "Lightning and Lightning Arresters." W.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, Wednesday, November 9, 1898. Vice-President James Christie in the chair.

Mr. A. E. Outerbridge, Jr., presented a paper on the "Mining and Minting of Gold and Silver." The subject was illustrated with the aid of lantern slides exhibiting the processes of coining and assaying as practiced in the mints, and by the exhibition of a number of ancient and rare coins. These were projected by Mr. Fred. E. Ives, in apparent stereoscopic relief with the aid of a simple magascopic attachment to the lantern which he had devised.

Mr. Oberlin Smith, of Bridgeton, N. J., in the discussion which followed, gave an interesting exhibition with the aid of lantern slides, of a set of improved coining presses and other minting machinery, made by the Ferracute Machine Company, of Bridgeton, N. J., for one of the Chinese provinces. He gave an entertaining account of the difficulties and vicissitudes encountered in the task of sending the plant into the far interior of China.

Mr. Outerbridge followed with a communication on "The Microstructure of Bronzes," in which he called attention to the limitations of the method of microscopic examination for determining the physical qualities of the bronzes. The speaker illustrated his remarks by the exhibition on the screen of a series of photographic enlargements of microphotographs made from the same piece of metal under varying conditions.

*Special Meeting*, Wednesday, November 23, 1898. President A. E. Outerbridge in the chair.

The meeting was devoted to the discussion of the papers read at the preceding stated meeting, and to the discussion of the subject of "Specifications on Structural Steel and Rails." (The several subjects here referred to with discussion thereon will be published in due course.)

The meeting voted to recommend to the Institute the advisability of the Franklin Institute uniting as a body with the International Association for Testing Technical Materials. W.